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The effects of access regulation on investment and the implications for an optimal access pricing policy

Michael A. Hellwig

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Abstract

This study examines the effects of access regulation on investment in the telecommunications sector from a static and a dynamic point of view. In that context, it reviews the relevant theoretical literature and also surveys empirical evidence. From these insights, it derives implications for an optimal access pricing policy. For this, two scenarios with different policy goals are distinguished, which are motivated from a distinct interpretation of the empirical evidence: Since entrants seem to be stuck seeking access to the incumbent's last mile infrastructure, the failure of investment in bypassing infrastructure can either be attributed to non-feasibility or to an inadequate implementation of the ladder-of-investment approach. In this regard, the regulator might then decide whether to promote more static or more dynamic efficiency depending on whether he acknowledges a business case for the replication of the incumbent's last mile infrastructure by entrants. Yet, a trade-off exists between both. Actively promoting investment is at the expense of current consumer welfare due to a higher access price. In return, however, consumers then benefit from the emergence of enhanced infrastructure, which provides a wider choice of services.

From a static perspective, a cost-based access price should be set for old and next-generation infrastructure in order to promote service-based competition leading to lower retail prices. A replication of the last mile infrastructure is then not strived for. From a dynamic perspective, regulation should comprise a dynamically increasing above-cost access price for the old network and a likewise high access price for the new network. Thus, investment in bypassing infrastructure by entrants is triggered and facility-based competition emerges.

Moreover, this study assesses whether these access pricing policies also fulfil their goals if competition from an unregulated cable network is present (whereas the previous analysis abstracts from it). The access pricing policy of the first scenario fails as the incumbent's investment is hampered and the cable operator might monopolize the broadband market for higher quality services. Accordingly, an adjusted access pricing policy is suggested: a cost based-access price for the old network and an above-cost access price for the next-generation infrastructure. Thus, the incumbent's investment incentives can be preserved in order to maintain future facility-based competition for higher quality services. In contrast, the access pricing policy of the second scenario can continue to trigger investment by entrants. Yet, while already facing facility-based competition between the DSL and the cable network, the regulator has to decide whether he still wants a further replication of the last mile infrastructure.

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This working paper is the result of a research project that the author conducted for ACM under supervision of **Robert Stil** and **Jarig van Sinderen** of the Office of the Chief Economist. The paper is based on the author's Master Thesis with the same title. The author wants to thank the colleagues at ACM for their valuable comments.

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List of Abbreviations

ACM	Autoriteit Consument & Markt (Netherlands Authority for Consumers and Markets)
DSL	Digital Subscriber Line
ECPR	Efficient Component Pricing Rule
ECTA	European Competitive Telecoms Association
EU	European Union
HHI	Herfindahl–Hirschman Index
LLU	Local Loop Unbundling
LRIC	Long Run Incremental Costs
Mbps	Megabit per second
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary least squares
OPTA	Onafhankelijke Post en Telecommunicatie Autoriteit (Netherlands Independent Post and Telecommunications Authority)
UK	United Kingdom
VDSL	Very-high-bit-rate Digital Subscriber Line

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1 Introduction

One of the main tasks of the ACM in the telecommunications sector is the three-yearly market analysis. These analyses investigate the need to continue, modify or withdraw sector-specific access regulation in the relevant markets in the electronic communications sector.

The regulatory approach under the Dutch Telecommunications Act means in essence that competition is promoted by requiring market players with significant market power at the network level to provide access to their networks to third parties. Entry of third parties would enable the development of competition in the underlying retail markets. If these third parties also invest in their own networks, a more sustainable form of competition can develop, which eventually could survive without specific access regulation. The investment-ladder regulatory approach aims to stimulate these parties to incrementally invest in their own infrastructure. However, is not obvious whether third parties using regulated network access will invest in their own infrastructure. On the one hand, such investments might not be financially viable. On the other hand, access regulation itself might have an influence – not only on entrants but also on the incumbent's investment.

In light of the new regulatory style of the ACM, which places the effects of interventions at the centre of the strategic approach, there is a need for better understanding the impact of access regulation on market developments in the telecommunications sector. The aim of this study is to provide an appropriate basis for decision-making. Besides studying the relevant theoretical and empirical literature, it derives an optimal access pricing policy depending on whether investment is actively strived for or not. The following subsections provide further background motivating and introducing this study.

1.1 Access and competition

The incumbent, often a former (state-owned) monopolist, possesses a whole fixed-broadband network, which connects end-consumers to the internet via his local and backbone (i.e. the long-distance) infrastructure. An entrant that wants to enter into competition on the broadband retail market can decide to roll out a parallel network. Yet, as this comprises immense investment efforts, it may also decide to seek access. Technically, this is called one-way access since only the entrant needs access to the infrastructure of the incumbent, but the reverse is not true.

Access can take place at several levels. Firstly, the entrant could decide to simply resell the incumbent's broadband service. It then does not offer any distinct service. Secondly, the entrant

might also seek access at the wholesale level. This implies that the entrant only relies on the incumbent's local network but employs its own equipment up to this point (alternatively, it might seek access to other backbone-network owners). Thus, it is able to offer value-added services but it is restricted by the characteristics of the incumbent's offered bitstream lines. Thirdly, the entrant might also decide to only access the incumbent's last mile infrastructure, which ultimately connects to the buildings of end-consumers. Thus, it would lease only the incumbent's local loop but has invested in the whole infrastructure up to this point. This allows offering a wider range of distinct services, like e.g. differentiated speeds (which are then only limited by the technology of the incumbent's last mile infrastructure).

These kinds of access lead to service-based competition, which describes the case in which the entrant inevitably relies on the facilities of the incumbent and both then compete for service at the retail level. In the case in which the entrant decides to replicate also the last mile infrastructure to the end-consumer, it eventually bypasses the incumbent's infrastructure. This situation then implies facility-based competition meaning that firms compete in the retail market employing their own infrastructures. The entrant is thus no longer restricted by the incumbent's choice of access terms, service and technology.

Though, the incumbent may not always be willing to grant entrants access to his infrastructure and therefore a regulator might decide to mandate access. The effects of this mandated access are the subject of this study.

1.2 Goal(s) of access regulation

The European regulatory framework for electronic communications aims at introducing competition in the formerly monopolized telecommunications markets in EU Member States. The principles of the framework are laid down in a set of European directives, of which the framework directive and the access directive are the most relevant for this study. These directives are implemented in the Dutch Telecommunications Act.

The ultimate goal of the introduction of access regulation in the telecommunications sector is a situation of sustainable competition, which can be defined as a situation of effective competition that can sustain without the aid of specific access regulation. In fact, this ultimately aims for facility-based competition and thus a replication of infrastructure. The attainment of the ultimate goal is supported by intermediate goals intended to start and facilitate the process of replication. They comprise the emergence of service-based competition and the assurance of entrants' investments in their own infrastructure. Accordingly, the requirements on the access price are comprehensive: to promote

efficient entry and not to distort any investment decisions. (European Commission, 2013)

1.3 Research questions and approach

The policy goal of sustainable competition, thus, eventually aims for facility-based competition. In addition, service-based competition is simultaneously promoted. Both forms of competition are indeed interrelated, but in what way? The current regulatory framework presumes a complementary relationship: Service-based competition would facilitate the emergence of facility-based competition. However, depending on the access pricing policy, service-based competition could also be profitable for access seekers so that their investment might even be hampered. Besides, access regulation especially concerns the incumbent as he is mandated to provide access. In times of increasing demand for broadband services of higher quality, the design of the access pricing policy might also affect his investment incentives to upgrade his infrastructure.

Accordingly, the following questions are addressed in this study: Firstly, what effects of access regulation on investment does the recent theoretical and empirical literature detect? Secondly, anticipating a tension between the policy goals to strive for both service-based and facility-based competition, what should an optimal access pricing policy look like to reach these goals? And thirdly, how does this translate to the specific case of the Netherlands?

These questions already depict the approach of this study. Based on a comprehensive review of the existing theoretical and empirical literature, their findings are assessed while deriving an optimal access pricing policy. Additionally, these policies are evaluated with respect to their applicability to the Dutch broadband market.

1.4 Limitations and remarks

Especially the application to the Netherlands reveals a shortfall of the examined theoretical studies. They do not account for a competing cable network. They solely focus on a situation of an incumbent and an entrant on the telephone network, and investigate the effects regarding service-based competition on it. The emergence of facility-based competition then entails that an additional infrastructure will develop. The presence of a cable network, however, implies that facility-based competition is already present. As a result, the insights from the treated literature cannot be directly transferred to the Dutch broadband market, which, to some extent, is rather the final outcome of their analyses. Hence, the theoretical sections 2, 3 and 5, which do not account for a competing cable network, are more of relevance for other countries with less developed cable networks. However,

section 6 with the application to the Netherlands explicitly accounts for a competing cable network and presents related theoretical works.

When speaking about static and dynamic efficiency, the definitions of Van Dijk et al. (2005) are adapted. They state that static efficiency is maximized when both consumer and producer welfare (i.e. social welfare) are maximized given that production is carried out at the lowest possible costs. Enhanced dynamic efficiency would then imply the maximization of the present value of the future stream of static social welfare. Yet, this study only focuses on consumer welfare since regulatory authorities often rather emphasize consumer welfare. In this study, the concepts of static and dynamic efficiency are assumed to correspond to service-based and facility-based competition, respectively. That is, from a static point of view (focusing on one period of time) consumers benefit the most from low retail prices. Thus, their welfare can be increased the most by promoting competition in the current period. This can be achieved by mandating access, thereby implying service-based competition. Contrary, from a dynamic, long-term point of view, consumers can obtain higher welfare by means of an increased choice of service quality. Since service-based competition, however, implies that services are limited by the incumbent's quality of infrastructure, such an increased welfare can only be attained by a new or improved infrastructure. Thus, investment is necessary. In the end, facility-based competition emerges, but some current welfare could be sacrificed for it. Accordingly, in this study, static and dynamic efficiency differ in their consideration of investment.

A remark is also necessary on the relationship between investment and innovation. In the telecommunications sector, the innovating act itself usually does not take place within the sector; newly developed technologies are in fact only adopted here. Innovation is thus carried out by investment. But not every investment also resembles an innovation. Pure duplication of lines (with the same quality) clearly is not an innovative investment, but introducing VDSL technology on a legacy copper network or building an alternative fiber network, in contrast, are. Thus, investment comprises innovation. Therefore, this study will rather refer to investment as a general term than distinguish between investment and innovation.

Lastly, it should be mentioned that this study takes an economic perspective and disregards any legal aspects of access regulation.

1.5 Structure

Section 2 describes, from a static point of view, the situation in which an incumbent can decide whether to allow access to his network. Additionally, the role of regulation is elaborated on. Section 3

takes the dynamic perspective and explains the impacts of access regulation on the investment incentives of both the incumbent and entrants. Thereby, it is also distinguished whether an old infrastructure is prevailing and regulated. Here, the main mechanisms of important, theoretical models are presented (a more in-depth description of these models can be found in the appendix). The subsequent section summarizes empirical evidences. Section 5 processes these findings and derives implications for an optimal access price with the help of two scenarios, which stress static and dynamic efficiency, respectively. Section 6 examines how these implications translate to the Dutch case. Here, competition from a cable network is present, which the previous sections abstract from. Finally, section 7 concludes summarizing the main findings.

2 Theory on static efficiency

Maximization of static efficiency comprises the maximization of social welfare. This will eventually be reached when services are priced to their marginal costs given that production is carried out at the lowest possible costs (Van Dijk et al., 2005). Solely focusing on the short run, static efficiency can be achieved by promoting competition. This section shows how this translates to the telecommunications sector, in which competitors require infrastructure for the provision of services.

2.1 Access without regulation

In the telecommunications sector, there is typically a vertically integrated firm, the incumbent, which owns the network infrastructure and provides service at the retail level. Thus, he is active in the upstream market as well as in the downstream market. Firms that want to enter the downstream market, i.e. to provide their services to consumers at the retail level, require an appropriate infrastructure to reach consumers. They might decide to roll out their own infrastructure. However, whereas the backbone infrastructure is less expensive to build and/or the leasing of backbone infrastructure is eased by effective competition among respective access providers, firms are dependent on the incumbent in order to access end-consumers. The incumbent possesses the last mile infrastructure whose replication is only feasible at high costs. Yet, taking a static perspective, such investment is disregarded. Thus, the relevant question is whether the incumbent would deliberately grant access to his infrastructure in the absence of regulation.

The previous description reveals a dependency of the entrant on the incumbent. In contrast, the incumbent is not reliant on the entrant. Thus, this situation of one-way access is generally not characterized by a “double coincidence of wants”, in which both firms would together be able to generate a surplus and hence would privately negotiate on its division (Valletti, 2003). Since the entrant would compete with the incumbent at the retail level, the incumbent would face reduced retail profits and hence is less likely to grant access. This will imply a situation of foreclosure in which the incumbent either denies access at all or stipulates an access price which is so high that the entrant has to raise the retail price for its service and thus loses consumers to the incumbent. Eventually, it will then leave the market putting the incumbent in a monopolistic situation at the retail level. (Valletti, 2003)

Still, it might be possible that the incumbent deliberately grants access to the entrant if the latter is able to provide better services. Thus, the entrant could attract more consumers in case not all consumers have been in the market so far, or it generally raises their willingness-to-pay otherwise.

The entrant is then able to increase demand and generates more retail profits. But the incumbent will accordingly stipulate such an access price that he absorbs these profits from the entrant. (Vareda, 2007)

It does not matter whether the incumbent might directly be in a monopolistic position or whether he might appropriate profits from an innovative entrant by means of a high access price; in any case, this yields high retail prices and a lack of effective retail competition. This goes along with hardly any consumer surplus and hence reduced social welfare. Thus, static efficiency is low and consumers might also suffer from a decreased variety of service if entrants are foreclosed.

2.2 Access with regulation

In an unregulated setting, it is unlikely that the incumbent voluntarily grants access (except if the entrant is able to expand the market). From a static point of view, however, the provision of access introduces competition at the retail level. Monopoly profits then vanish thereby reducing retail prices and increasing social welfare. But, the regulator might not only want to mandate access to the incumbent's infrastructure. He would also set an access price to impede that the incumbent extracts profits from entrants by stipulating too high access fees, which would otherwise inflate retail prices.

Given that the incumbent encounters costs in his upstream segment for every consumer he serves at the retail level, it is first-best (i.e. aiming at the maximum of static efficiency) for the regulator to set the access price equal to these marginal costs. In this manner, it is possible to provide a signal to the entrants ensuring efficient entry. If entrants can offer services that are substitutes to the incumbent's service, they will enter as long as they are as efficient as the incumbent. That is, having to pay an access fee that is equal to the costs that the incumbent would actually pay to himself, firms enter if they can offer comparable retail services at least at the same costs. (Armstrong, 2002)

Hence, foreclosure can be prevented. In addition, consumer welfare is increased as service-based competition develops. Retail prices decrease due to the entry of cost-efficient firms. Yet, an access price set below marginal costs can lead to inefficient entry (Valletti, 2003). The terms of access may then be unduly generous for entrants so that inefficient firms could operate profitably. Conversely, if the access price is set above marginal costs, fewer firms will enter than socially optimal as they receive too high a cost signal.

Though, when abandoning the static perspective, an access price set at marginal costs can hamper the firms' investment incentives as the next section shows.

3 Theory on dynamic efficiency

In contrast to static efficiency, dynamic efficiency is maximized by maximizing the present value of the future stream of static social welfare. Accordingly, dynamic efficiency is improved by innovations in products and/or production. Yet, such innovations may require large investments and only take place if the investor is able to recover its costs. For an active promotion of investment, a temporary curtailing of static efficiency has to be accepted. That is, access may not be priced according to marginal costs but at a level that promises the investor a reasonable return on his investment, which otherwise is less likely to be undertaken. (Van Dijk et al., 2005)

Hence, a tension arises. The regulator faces a trade-off between static and dynamic efficiency. If he wants to increase consumer welfare in the long run by inducing investment in better infrastructure, providing incentives by means of the access price requires it to be at least above marginal costs. However, this implies reduced consumer welfare in the short run. This section deals with this trade-off and presents respective insights from theoretical studies on the effects of access regulation on investment. For this, a brief background on access pricing is provided first. After this, the dynamic situation without access regulation is described. And subsequently, the impact of access regulation is addressed. It should be kept in mind that the theory outlined in this section abstracts from cable competition.[1]

3.1 Access pricing

In the static case, it is first-best to set the access price equal to the marginal costs of providing access in order to avoid distortions in retail prices and to promote efficient entry of entrants. However, when also taking investment into account, it is necessary to compensate the incumbent for the fixed costs when mandating access to his infrastructure. Optimally, this would be achieved by a governmental lump-sum payment, which, however, is not feasible (Canoy et al., 2003). Hence, the access price has to include a mark-up for fixed costs. Several ideas exist on how to design the access price in order to compensate the incumbent for the incurred costs. A brief, non-exhaustive overview is given in the following. It is to mention that other concepts exist, which are, however, disregarded as the focus lies on access pricing.

From a static perspective, Ramsey pricing intends to select optimal access *and* retail prices, which permit the recovery of fixed costs (so that the incumbent breaks even), thereby maximizing

[1] Section 6 accounts for a competing cable network and also provides the scarce theoretical insights.

social welfare. Yet, Ramsey pricing can be difficult to apply as the regulator is required to have full information regarding cost and demand. Under the Efficient Component Pricing Rule (ECPR), access prices are chosen while taking the price setting in the retail market as given. The focus is rather on cost recovery and productive efficiency than on social welfare maximization. Assuming homogenous retail products and a contestable market, ECPR requires the access price to be equal to the incumbent's direct marginal cost plus the opportunity cost of providing access. The latter entails a compensation to the incumbent for revenue losses that accrue when not the incumbent himself but the entrant serves a consumer. Hence, there is revenue-neutrality for the incumbent. Moreover, ECPR ensures that only more cost-efficient firms enter as they receive a correct cost signal. (Canoy et al., 2003; Valletti, 2003)

With regard to the changing character of the telecommunications market, dynamic pricing rules have been conceived. On the one hand, there are backward-looking access pricing rules that are based on the incumbent's historic costs in order to compensate him for his accrued investment costs. Yet, they may weaken the incentives for cost-efficient investments and the access price could therefore become quite high. On the other hand, forward-looking access pricing rules account for technological progress and correct any cost-inefficiencies of the incumbent. The access price is derived from benchmark costs of an efficient cost-minimizing firm using the latest available technology. The network owner is thus incentivized to reduce inefficiencies. For instance, such an access pricing rule can be based on Long Run Incremental Costs (LRIC). (Canoy et al., 2003; Guthrie, 2006)

Criticism on forward-looking cost-based access pricing rules

Even though forward-looking cost-based access pricing rules compensate for investment costs better than static access pricing rules, they are also contested. This criticism is drawn from the fact that such access pricing rules also do not adequately account for the incurred costs. Since the compensation is calculated from the currently available technology[2], quick technological progress would hamper the recovery of the actual investment costs (Hausman, 1999).

Moreover, there is an asymmetry of risk, which the users of infrastructure bear. When a firm invests in infrastructure, it makes an irreversible investment and must account for the opportunity costs of capital in good *and* bad states. An entrant, however, does not face the whole risk of an unsuccessful investment. If market conditions turn out to be bad, it can reduce losses by not seeking

[2] For instance, the Dutch regulator, ACM, conducts the appropriate valuation by employing the principle of Modern Equivalent Assets.

access. Thus, mandated access offers a risk-free option to the entrant. Pindyck (2007) accordingly suggests that access prices should incorporate a mark-up in order to account for this option and to compensate incumbents for the asymmetric risk. (Pindyck, 2007)

Furthermore, Jorde et al. (2000) point out that LRIC pricing increases the incumbent's cost of equity as his return on assets becomes more volatile with respect to changes in demand. In times of weak demand, entrants might rather decide to seek access thereby potentially lowering the incumbent's return. In contrast, with strong demand, entrants might then invest themselves, which could also hamper the incumbent's return as he faces more competition then. Hence, the incumbent does not reciprocally benefit from good times. Thus, cost-based access charges under-compensate the incumbent, whereas the entrant gets a valuable opportunity to resolve uncertainties about market developments while seeking access to the incumbent's infrastructure. (Jorde et al., 2000)

To conclude, critics bring forward that forward-looking cost-based access pricing rules do not account for some important cost components and thus may reduce investment – not only by the incumbent but also by the entrant as the latter does not face the real costs of access.

3.2 Access and investment without regulation

From a static point of view, which disregards investment, the incumbent would foreclose entrants thereby remaining both the monopolistic owner of infrastructure and the sole provider of retail service. The incumbent might only deliberately grant access to his infrastructure if the entrant is able to provide improved and/or more heterogeneous services that enable it to attract more consumers than the incumbent. Though, the incumbent might then stipulate a high access price in order to absorb profits from the entrant. In any case, static efficiency will be low and consumers pay too high retail prices (either due to monopolistic price-setting or due to the passing on of high access fees). Yet, these implications from the static section are crucially altered when also considering investment possibilities. Investment by entrants could then possibly lead to facility-based competition. This would put more severe competitive pressure on the incumbent and he accordingly alters his behaviour.

In general, according to investment theory, firms decide to invest when a project's expected return is at least equal to its cost of capital. That is, they do not only consider the direct costs of investment but rather weigh the possible profits of an investment against its opportunity cost, corresponding to the return on alternative investments with similar risks.

For the further analysis, investment can be classified into three types: Firstly, investment which is aimed at reducing the costs of maintaining a prevailing infrastructure. Secondly, investment which

enhances the prevailing infrastructure and enables the provision of better service thereby increasing demand, i.e. being able to attract more consumers. And thirdly, investment in new, alternative infrastructure. The first two types of investment only apply to the incumbent as he owns the prevailing infrastructure. The third type of investment applies to both the incumbent and the entrant. That is, it mainly concerns the replication of the incumbent's last mile infrastructure. The incumbent may roll out fiber lines besides his copper lines, and the entrant could install its own bypassing infrastructure (of either copper or fiber).

3.2.1 Investment in prevailing infrastructure

Although employing a dynamic perspective, the incumbent might – similarly to the static case – deliberately grant access to an entrant if it is able to provide enhanced service and, thus, to attract more customers. As already elaborated, he then stipulates a high access price in order to appropriate the entrant's profits. But as the access price is translated to higher retail prices for the entrant's service, he will not set the access price too high so that the demand for the entrant's service is not reduced. The underlying reason is that this would mean less access charge revenues for the incumbent. (De Bijl & Peitz, 2007)

How does this situation change the incumbent's incentives to conduct investment of the first two types? Regarding the first type, the analysis by Vareda (2007) indicates that investment in cost reductions could be less likely as this gives the incumbent a cost advantage, which would attract customers away from the entrant thereby lowering his access charge revenues. The incumbent would thus no longer benefit from the entrant's ability to attract more consumers. This result of reduced investment, however, hinges on the assumption that the incumbent exploits his cost advantage and passes the cost reductions on to his customers. Yet, this assumption can be questioned. Why should a profit-maximizing incumbent not decide to invest in cost reduction and keep the marginal benefits to himself – especially since such cost reductions would only benefit him? That the incumbent engages in cost reductions without access regulation can, therefore, not be precluded.

Regarding the second type, investments in the quality of infrastructure are likely to benefit every user of infrastructure. Assuming that the entrant provides better service than the incumbent, the incumbent might still invest since this does not only increase his subscribers but also especially those of the entrant, and thus the access charge revenues he receives (Vareda, 2007). De Bijl and Peitz (2007) point out that the incumbent's incentive to invest in quality seems independent of the degree of competition as such investment inherently triggers more demand. This implies that even

when the entrant is not able to provide better service and is accordingly foreclosed by the incumbent, investment in the quality of infrastructure will be conducted by the incumbent – only given that it pays off.

3.2.2 Investment in new infrastructure

Regarding the third type of investment, both the incumbent and the entrant can decide to roll out new infrastructure. In order to better analyse their incentives, two situations can be distinguished. Firstly, a situation in which the incumbent owns the prevailing infrastructure of old technology, which cannot be upgraded anymore. Better quality can only be achieved by rolling out new infrastructure of enhanced technology. The second situation concerns areas without any prevailing infrastructure, e.g. development areas.

Both situations are accordingly characterized by high investment costs. Though, the theoretical literature acknowledges that such investment will eventually occur. On the one hand, technological progress is assumed to drive down adoption costs so that, at some date, investment will be affordable (Bourreau & Doğan, 2005). On the other hand, demand might sufficiently rise so that the expected return on investment increases and the high costs can be outweighed (Hori & Mizuno, 2006). Importantly, this affects both parties alike.

3.2.3 Investment in new infrastructure with prevailing infrastructure

For the situation with a prevailing old infrastructure, this implies that any entrant is likely to eventually invest in bypassing infrastructure, thus yielding a state of facility-based competition. From the incumbent's point of view, he will face tougher competition; his monopolistic position is challenged. Therefore, as pointed out by Bourreau and Doğan (2005), he has a clear motivation to delay the occurrence of facility-based competition as long as possible, i.e. to deter entrants from investing. His instrument to do so is to deliberately grant access to his prevailing infrastructure. But he would not absorb all profits from the entrants (as in the static case). He would rather warrant that an entrant makes some profits while seeking access. In this way, the incumbent introduces additional opportunity costs to the entrant's investment decision: If the entrant decides to invest, it would forego these profits (i.e. the so-called replacement effect; see also section 3.3.2). The lower the incumbent sets the access price, the lower will indeed be his access charge revenues. But the incumbent would even accept this in order to delay the entrant's investment even more because the roll-out of new infrastructure by the entrant would imply a loss not only of his monopolistic position but also of any (profitable) access charge revenues. (Bourreau & Doğan, 2005)

Yet, in contrast, it is also possible that the incumbent forecloses the entrant and denies access even though it might eventually invest in alternative infrastructure. This notion is, for instance, brought forward by Avenali et al. (2010) who see service-based competition as a precondition for facility-based competition. An entrant might indeed be able to roll out its own infrastructure, but consumers would perceive the entrant as a provider of low quality if it was not able to build up reputation beforehand. The entrant's investment then does not pay off and is omitted. Intending to impede the occurrence of facility-based competition, the incumbent would accordingly not grant the entrant the possibility to gain reputation and would foreclose it. (Avenali et al., 2010)

Summing up, in a situation with a prevailing old infrastructure but without regulation, the incumbent would strive to impede the entrant's investment by any means. Would the incumbent, however, invest himself? This seems possible since, at some point, investment will be profitable (due to technological progress or increased demand). The unregulated setting with voluntary access provision could even accelerate investment to some degree as access charge revenues from the old infrastructure might provide some funding. Alternatively, the lack of competition to the new infrastructure could enable the incumbent to set such retail prices that his investment pays off earlier.

3.2.4 Investment in new infrastructure without prevailing infrastructure

Regarding the situation of development areas, investment decisions are not delayed by a prevailing old infrastructure. The roll-out of new infrastructure would occur at the time when investment becomes profitable (due to technological progress or increased demand). However, firms might be incentivized to preempt each other if they expect high monopoly rents after their investment; this accelerates investment (Hori & Mizuno, 2009). That is, there is an investment race to roll out new infrastructure.

With respect to geographically-varying investment costs (e.g. due to different densities of population), three areas might emerge: One with two networks as both firms have invested, one with one network as in the respective areas investment costs are so high that only one firm can profitably enter, and finally one where none of the firms has invested due to too high investment costs (Bourreau et al., 2012). Which firm will cover an area with monopolistic infrastructure depends on whether one firm has a cost advantage over the other firm (Lestage & Flacher, 2010). If both firms face the same costs, both are equally likely to invest. If the incumbent features an information advantage due to his infrastructure elsewhere and/or exhibits a cost advantage, he is likely to invest first. Otherwise, the entrant might also invest first.

Notwithstanding and similarly to the aforementioned analysis, the investing firm might deliberately

grant access to the other firm if the latter has the ability to provide better service and can attract more consumers (but thereby appropriating the entrant's profits) (Lestage & Flacher, 2010).

3.3 Access and investment with regulation

The analysis of the impacts of access regulation on investment follows the circumstances touched upon in the previous section. The following subsections accordingly cover the investment incentives of the incumbent and of the entrant distinguished by the presence of a prevailing infrastructure. Besides briefly recapping the situation without regulation, the subsections explain how mandated access changes the initial incentives. These impacts are derived from relevant theoretical models. In that context, the focus is on presenting their main mechanisms in a non-technical way. If their results are based on crucial assumptions, this is mentioned. In addition, a more thorough description for the respective, theoretical studies is provided in the appendix. Again, it is to stress that these models abstract from a competing cable network.[3]

Yet, a preliminary remark is necessary about the credibility of the regulator to commit to set specific access prices ex-ante. As the following subsections will show, the provision of investment incentives mainly works by means of access prices set higher than marginal costs. Investment will only occur, if the regulator can credibly commit ex-ante to keep the access price on a certain level (for a certain time). However, if he reneges after the investment is conducted and sets the access price equal to marginal costs (since he rather wants to enhance static efficiency), the investing firm will anticipate this, and might accordingly not invest being unable to recover its investment costs (Avenali et al., 2010; Vareda, 2007). This commitment problem is also of relevance if the regulator turns away from an earlier guaranteed above-cost access price. The investing firm's consideration of costs and benefits then no longer incorporates the higher expected profits. Investment will then not be accelerated and only takes place at its initial date.

3.3.1 Effects on the incumbent's investment in his prevailing infrastructure

Regarding the incentives of an incumbent to conduct investment that improves his infrastructure, the theoretical literature studies how the introduction of service-based competition alters his investment decision.

Without access regulation, the incumbent has always an incentive to upgrade the quality of his infrastructure if this results in more demand for his service, i.e. if he can attract more consumers or

[3] Section 6 accounts for a competing cable network and also provides the scarce theoretical insights.

increase their willingness-to-pay in this manner. This investment incentive is independent of the existence of entrants, but he would also conduct such investments if the entrant benefited since he could then appropriate the entrant's profits by stipulating a high access price. Though, if entrants are not able to provide enhanced services that can attract more consumers, the incumbent would not grant access to them. (De Bijl & Peitz, 2007)

Accordingly, access regulation aims to promote entry. The entry of more cost-efficient firms will also drive down retail prices. In order to enable the entrants to make the right entry decision, the regulator would set the access price equal to the incumbent's marginal costs of providing access. In general, this is revenue-neutral for the incumbent as he then would make neither profits nor losses while allowing entrants to use his lines. Yet, this reduces his incentives to invest in his infrastructure since such an access pricing policy does not account for the investment costs.

The impact of the level of access price

If the regulator sets ex-ante the access price above marginal costs, the incumbent benefits from increased access charge revenues, which he receives from the entrant. As the incumbent is interested in maximizing his profits, he would conduct any investments that could increase the demand for his services thereby also enabling him to charge higher retail prices. This is of course a general incentive. But with a given (profit-promising) access price, the incumbent has even an reinforced incentive to invest if also the demand for the entrant's service increases resulting from this investment and/or if the entrant generally provides better retail service. This gives him additional access charge revenues (since with more subscribers, the entrant uses more lines and pays more access fees). (De Bijl & Peitz, 2007)

With respect to investments in cost reduction, the incumbent's incentives to undertake such investments could be lower in case he passes these cost reductions on to consumers (but such a behaviour seems implausible for a profit-maximizing incumbent). This would imply that he attracts consumers away from the entrant, and thus would forego profits from access charges. (Vareda, 2007)

In contrast, lowering the access price intensifies competition by more entry. This would incentivize the incumbent to invest more in cost reduction in order to gain a cost advantage and to accordingly get more subscribers. However, his incentives to invest in quality are then reduced as the increased demand would also benefit the entrant. (Vareda, 2007)

Non-price foreclosure

Mandating access also aims to prevent the incumbent from foreclosing entrants. Yet, the theoretical literature also points out that, when the access price is set at marginal costs, the incumbent might employ other, non-price forms of foreclosure. On the one hand, he might engage in overinvestment in order to drive the entrant out of the market. This might occur when the incumbent benefits more from an investment than the entrant, i.e. when he is able to offer better services after the investment so that he would attract all the consumers (Foros, 2004). On the other hand, if the incumbent benefits less from an investment than do entrants do, he is less incentivized to invest at such an access price. A lack of investment might then entail a low level of the quality of infrastructure, which might even be too low for entrants to effectively provide their services. Thus, with low or no investment, entry might then be unattractive for firms so that underinvestment actually leads to foreclosure (Kotakorpi, 2006).

3.3.2 Effects on the entrant's investment in bypassing infrastructure

With respect to the investment incentives of the entrant, the literature can be divided into two strands depending on whether service-based and facility-based competition are seen as complements or not. Yet, they disregard issues concerning the interrelation between old and next-generation infrastructure, which is the focus of section 3.3.4.

Service-based and facility-based competition are not complementary

The idea that service-based competition is not a necessary precondition for facility-based competition stems from the assumption of declining adoption costs. The work of Bourreau and Doğan (2005, 2006) exemplifies this idea. Technological progress is anticipated to drive down the costs for entrants to bypass the incumbent's local loop. Thus, ultimately there will be a point when the cost side of the entrant's consideration of costs and benefits will be sufficiently low so that the entrant at least breaks even and invests in bypassing infrastructure.

Yet, the possibility of leasing the local loop from the incumbent might delay this adoption. If the access price is set in such a way that the entrant gets some profits from access seeking, this adds to the cost side of investment in the form of opportunity costs. That is, once the entrant decides to invest in bypassing infrastructure, it effectively foregoes these profits. Hence, in any consideration of costs and benefits, the entrant takes these foregone profits into account. This mechanism is also

known as the replacement effect: The replication of infrastructure by an entrant[4] can be hastened by higher access prices or accordingly delayed by means of more favourably access prices. Without regulation, the incumbent is assumed to have an incentive to do the latter in order to postpone the occurrence of more severe facility-based competition. (Bourreau & Doğan, 2005)

Regulation would therefore aim at higher access prices in order to reduce such additional opportunity costs. In an extreme case, the access price could be set prohibitively high thereby eliminating these opportunity costs (Bourreau & Doğan, 2006). While access-seeking would then be forbidden, the entrant's roll-out of infrastructure is then no longer delayed and takes place at the initial date. Yet, this also implies a period of absence of any (service-based) competition and accordingly reduced consumer welfare since the incumbent then acts as a monopolist. Bourreau and Doğan (2005, 2006), therefore, suggest to set ex-ante a sufficiently low access price, which induces service-based competition, up to the social optimal date of adoption at which the access price should be increased.[5] This, in turn, abruptly reduces the entrant's opportunity costs thereby enforcing investment in bypassing infrastructure.

Service-based and facility-based competition are complementary

The other strand of literature considers service-based and facility-based competition as complements due to a reputation effect. Even though the entrant might be able to offer services of enhanced quality once it has rolled out a bypassing infrastructure, its services might still be perceived as of lower quality by consumers. A first-mover advantage of the incumbent might thus only be overcome by building up a consumer base by earlier engaging in service-based competition. In this sense, the incumbent has an incentive to foreclose the entrant in order to impede it from gaining reputation thereby making entry in facility-based competition unlikely. (Avenali et al., 2010)

The regulator can impede this foreclosure by mandating access. In the same manner as described above, a sufficiently low access price can be used to facilitate service-based competition. A dynamically increasing access price, to which the regulator commits ex-ante, then makes access-seeking less attractive (i.e. opportunity costs decrease) and induces the entrant to invest in bypassing infrastructure. This implies that facility-based competition will eventually occur.

The complementarity of service-based and facility-based competition also serves as the basis for the ladder of investment theory.

[4] This implies the "replacement" of the incumbent's infrastructure.
[5] The regulator does not increase the access price ad hoc but rather has ex-ante committed to do so at the pre-set date.

3.3.2.1 The ladder of investment

Cave (2006) develops the idea of the ladder of investment and its implementation. Based on an assessment by the regulator of the replicability of the individual network elements, these can be ordered from the easiest to the least replicable network element. This establishes the ladder of investment, which the entrants have to climb in order to ultimately bypass the incumbent's infrastructure by sequentially investing in their own infrastructure. The underlying idea is that facility-based competition requires transitory entry assistance, which, in fact, means to offer entrants the possibility to enter service-based competition at first. This will enable them to build up reputation and a customer base without having to carry the whole investment costs of replicating the incumbent's infrastructure at once. Moreover, this will provide entrants with the option to resolve uncertainty of market conditions (e.g. regarding demand and technology). The stage of service-based competition is thus a chance for the entrants to invest in experience (Bourreau et al., 2010).

Entrants will ideally climb up the ladder prompted by the attractiveness of the next rung and by the concern that their current rung will become less profitable. This necessitates intervention by the regulator. He sets ex-ante a dynamically increasing access price[6] in order to enforce the replacement effect (so that the entrant faces decreasing opportunity costs of investing and thus eventually invests instead of remaining at its current (profitable) rung). In practical terms, regulators should move away from cost-based access prices (which ensure that the incumbent can recover his investment costs) to higher prices (which then may also incorporate a mark-up e.g. in order to account for the risk-free option as described in section 3.1). (Cave, 2006)

The number of entry levels

Cave (2006) further points out that lifting up entrants by burning up lower rungs will imply that, at any given time, there effectively has to be only one level of entry. Hence, there are no different incentives for entrants entering on different rungs. This non-discrimination will avoid negative effects on the investment of existing entrants if late entrants might be privileged e.g. by an access price applied to the existing entrant's new infrastructure, which does not allow it to recoup its costs (Avenali et al., 2010). Cave (2006) acknowledges that late entrants then might have to face higher investment costs when entering the only available but higher rung. Though, he argues that the deregulated ("burned")

[6] Cave (2006) also proposes another mode of intervention: the withdrawal of mandatory access after a certain period (a so-called sunset clause). Yet, the theoretical literature seems to agree that, after this period, the incumbent – instead of charging a much higher access price in order to absorb more profits from the entrant – may charge too low an access price with the intention to further delay the entrant's investment in bypassing infrastructure and thus to avoid the more severe facility-based competition (Avenali et al., 2010; Bourreau & Doğan, 2005, 2006).

lower rungs will enable the late entrant to get access to these rungs at reasonable access prices resulting from the consequently emerged competitive wholesale market.

Yet, Bourreau et al. (2010) question whether such access would be granted, i.e. whether the developing wholesale market at the lower rungs would become monopolistic or competitive. This results from a dilemma that the owners of the infrastructure face: Granting access to late entrants might generate access charge revenues, but this would be contrasted with lower retail revenues as they could lose customers to the late entrants. Hence, they might not grant access. Nevertheless, this could, in turn, possibly incentivize the late entrant to directly decide to bypass the current rung. (Bourreau et al., 2010)

An old and a new ladder

Cave (2010) also applies the ladder of investment approach to the context of next generation networks. The presence of an alternative fiber network will eventually lead to the disappearance of the unbundled copper local loop as fiber lines could reach closer to consumers. The “unbundling” might then effectively take place behind the former local loop unbundling (LLU). Yet, such a distance-related displacement might not apply everywhere. Though, the presence of a next generation implies that the highest rung of the old ladder, the LLU rung, would vanish and existing entrants would, thus, either have to move up further by rolling out their own bypassing fiber network or have to switch to the bottom of the new ladder by seeking access to the new fiber network at the wholesale level.

The related theoretical literature can be grouped into two strands, which are discussed below. The first strand deals with the case in which firms race for the roll-out of new infrastructure in areas without prevailing (old) infrastructure (section 3.3.3). The other concerns the roll-out in case of a prevailing legacy infrastructure, which is regulated (section 3.3.4).

3.3.3 Effects on the investment in new infrastructure without prevailing infrastructure

3.3.3.1 The decision when to roll out new infrastructure

The literature on the roll-out of new infrastructure in areas without prevailing infrastructure effectively deals with investment rivalry settings. Here, two firms race to invest. Accordingly, there will be a leader investing first and a follower, which also invests but later. That the follower will eventually invest is a crucial assumption, which either stems from technological progress (which ultimately drives down investment costs (Vareda & Hoernig, 2010)) or from growing demand (which also

ensures that investment ultimately becomes profitable (Hori & Mizuno, 2006, 2009)). In the meanwhile, the follower might seek access to the leader's infrastructure.

In such an investment race, mandated access on any new infrastructure gives both firms an additional incentive to invest: the so-called pre-emption incentive. Winning the investment race would at least imply avoiding the payment of access fees. But winning could also entail obtaining profitable access charge revenues. This necessitates of course a high enough access price. Hence, the regulator's obvious parameter to reinforce the pre-emption incentive (and thus to accelerate investment) is the access price. (Hori & Mizuno, 2006; Vareda & Hoernig, 2010)

Yet, the access price also affects the follower's decision when to invest in bypassing infrastructure. As a high access price will also decrease the follower's opportunity costs of investing, it will accordingly invest earlier (i.e. the replacement effect). Consequently, the period in which the follower seeks access is shortened. Thus, the leader will also encounter a truncated period in which he benefits from access charge revenues. However, this might, in turn, induce the leader to delay his initial investment and thus the roll-out of new infrastructure in general. The regulator might, therefore, decide to set a lower access price. This clearly deters the follower from investing early as its opportunity costs are now higher. Yet, it might also reduce the leader's incentive to invest early as he will obtain lower access charge profits. If the access price is set too low so that the leader cannot even recover his investment costs, he will not invest until technological progress or growing demand have sufficiently driven down adoption costs. (Hori & Mizuno, 2006; Vareda & Hoernig, 2010)

The access price is, therefore, not only the instrument to accelerate investment in new infrastructure in general, but also to induce investment at the socially optimal date. Yet, as Vareda and Hoernig (2010) point out, a time-invariant access price cannot achieve a socially optimal investment by both the leader and the follower. Thus, a suitable remedy could be to commit ex-ante to ban access after a pre-set date. An access price set sufficiently high will ensure that the leader invests at the socially optimal date. Though, in order to induce the follower not to delay its investment but to invest at its socially optimal date, the access price has to be set prohibitively high from that date on. The replacement effect will kick in by eliminating the follower's opportunity costs of investment so that it then immediately invests. (Vareda & Hoernig, 2010)

3.3.3.2 The decision where to roll out new infrastructure

Related to investment rivalry models, which study when investment in new infrastructure will occur, there exists more recent literature examining where new infrastructure will be rolled out. This subject is motivated from the observation that new infrastructure mainly emerges in dense metropolitan

areas. Hence, this literature assumes investment costs to vary by area (e.g. due to a varying density of population (Lestage & Flacher, 2010)). Moreover, without the presence of a prevailing infrastructure, two firms are assumed to simultaneously decide whether or not to invest in each area.

Accordingly, without access regulation firms will roll out new infrastructure especially in areas with low investment costs and reduce their investment with rising investment costs. Thus, eventually there will be areas with two networks, with only one network and without any network. In the areas with one network, the respective firm might deliberately grant access to the other firm if the latter firm is able to provide better service. The former firm then absorbs the respective profits by setting a high access price. Otherwise, the former firm denies access to its infrastructure and acts as a monopolist. (Lestage & Flacher, 2010)

Mandated access can impede such foreclosure by introducing service-based competition in areas with monopolistic infrastructure. Yet, mandated access also affects the firms' investment decisions. This does not only depend on the level of the access price but also on how it differs across areas.

In general, a low access price makes it more attractive to seek access. This reduces the number of areas with two networks, where both firms would have invested without mandated access, because one firm might then rather seek access than invest. With a low access price, the access-providing firm faces lower access charge revenues than it would get if it voluntarily provided access in the unregulated situation. Thus, with a prospectively diminished return on investment it reduces its investment. This also reduces the number of areas where a single network would have emerged without regulation. (Lestage & Flacher, 2010)

Regionally-differentiated access prices

If the regulator sets an access price according to the marginal costs of providing access in each area, investment incentives are even more hampered. Areas with a single infrastructure might still emerge but with a smaller coverage. Yet, no area will emerge with two new networks. The reason is that access-seeking is more attractive than investing thereby lowering investment by both firms. (Bourreau et al., 2012)

If the regulator sets a uniform access price for all areas, this leads to more investment than in the previous case as long as this access price is higher than marginal costs. Firms now can get some profits while providing access to an entrant and thus are more incentivized to invest. There will be a higher total coverage of new infrastructure and even areas with two infrastructures will emerge. The latter also results from the possible occurrence of an additional late entrant which only seeks access but does not invest. Both former firms, which are about to invest, figure out that it is equally likely that

the late entrant seeks access to their infrastructure. This implies that they have an equal chance of getting access charge profits. Accordingly, they initially are more motivated to invest. (Bourreau et al., 2012)

Yet, access prices above marginal costs are at the expense of consumer welfare. Therefore, Bourreau et al. (2012) also study the case in which an access price at marginal costs is only mandated in areas with a single infrastructure. In contrast, providing access is obliged by the regulator in areas with two infrastructures, but the respective access price can be negotiated on a commercial basis. They show that this access regulation can increase total coverage. It especially enlarges the number of areas with two networks as the investing firms expect themselves to be the final access provider to the late entrant at a profit-promising access price.

3.3.4 Effects on the investment in new infrastructure with prevailing infrastructure

In contrast to the issue of investing in next-generation networks without prevailing infrastructure, the theoretical literature dealing with the migration from a legacy network to a next-generation network is rather young. The existence of a legacy network *with mandated access* crucially affects the incentives to invest in next-generation infrastructure. Of similar importance is whether the new network is also subject to mandated access.

3.3.4.1 The new infrastructure is not subject to access regulation

Regarding the situation of an unregulated new network, the firms' incentives to invest mainly depend on the level of the access price for the old infrastructure. But there are further decisive factors. Besides the height of investment costs, possible spill overs from the first-moving firm's investment or the consumers' valuation of new technology are assumed to play a role.

In general, it is possible that both the incumbent and the entrant are equally likely to invest, i.e. that they encounter the same investment costs (e.g. due to technological progress). However, the literature ascribes a cost advantage to the incumbent (e.g. due to better knowledge (Bourreau et al., 2011)) implying that he invests first.

The feedback effect of the access price for the old infrastructure

A subsequent question is then whether the entrant will follow and also invests in the respective areas with a now prevailing new infrastructure. Bourreau et al. (2011) argue that this could be more likely with higher spill overs from the incumbent's investment, i.e. the more the entrant can benefit from reduced costs (e.g. by a lower administrative burden). Still, the main instrument to trigger investment

by the entrant is the level of the access price for the old infrastructure. The higher the access price, the more likely is investment in an alternative network since the replacement effect makes seeking access to the old infrastructure less attractive for the entrant (by lowering the opportunity costs of investing). In turn, the entrant might then not only follow the incumbent but might also roll out new infrastructure in areas where the incumbent has not yet invested (Bourreau et al., 2011).

Any investment by the entrant has a feedback effect on the incumbent's investment decision. If the entrant has rolled out his own infrastructure, it is no longer relying on the incumbent's infrastructure in these areas. This implies that the incumbent no longer receives access charge revenues. Especially, if the access price for the old infrastructure is high (i.e. above-cost), the incumbent would lose profits. In the case of high spill overs from the incumbent's investment, which would make any investment by the entrant in the same areas more likely, the incumbent would accordingly reduce his investment in order not to forego these profitable access charge revenues. Bourreau et al. (2011) call this the wholesale revenue effect.

The consumers' willingness to switch

In contrast, Bourreau et al. (2011) also identify a negative effect of a low access price on the incumbent's investment incentives. An access price for the old network set at marginal costs implies higher service-based competition and thus reduced retail prices. In order to make consumers switch to the new network services, relative low retail prices for the new infrastructure might be necessary. This, in turn, lowers the profitability of any investment in next generation infrastructure, which therefore might be less likely to be conducted by the incumbent. Bourreau et al. (2011) label this the business migration effect. In this sense, they take a rather conservative view on the consumers' willingness to switch.

Brito et al. (2012) dwell on this issue and distinguish the extent of the innovation of the new network. Yet, in their setting, even a non-drastic innovation is able to increase the valuation of consumers and makes them likely to switch when they face comparable retail prices.

Since retail prices for the old network are affected by the access price, Brito et al. (2012) are able to elaborate on the likelihood whether service-based competition emerges on the unregulated new infrastructure, i.e. whether the incumbent would deliberately grant access to his new infrastructure. If there is a high access price for the old network, the retail price for the entrant's service is relatively high. An investment by the incumbent in new infrastructure then enables him to set also relatively high retail prices but in such a way that he attracts consumers away from the old network. Thereby, he will forego access charge revenues. But the incumbent can offset these losses by increased retail

profits on the new network. He, therefore, exploits his price-setting scope since he does not fear any competition from the entrant as the latter is left with high access fees and cannot compete over retail prices.[7] To further strengthen his competitive position, the incumbent would also deny access to his new infrastructure. (Brito et al., 2012)

This situation is altered in the case of a low access price for the old network. Even though employing the old technology, the entrant remains a competitor due to a low retail price for his service. The incumbent might then deliberately grant access to the entrant but stipulates such an access price so that he makes up at least for the loss of access charge revenues from the old network (thereby ensuring that the entrant seeks access). (Brito et al., 2012)

Summing up, Brito et al. (2012) show that the incumbent always invests at low and at high access prices for the old network (while the new one is unregulated). Still, they argue that, at an intermediate access price, the incumbent might not invest as the ex-post competition might be too strong. This, in turn, precludes him from demanding such an access price to balance the foregone access charge revenues from the old network. In addition, with a drastic innovation, the incumbent will always invest and foreclose the entrant since he does not fear any competition from it being left with the old technology (Brito et al., 2012).

Enhanced tension between static and dynamic efficiency

With respect to area-dependent investment costs and the respective investment incentives, three differently covered areas emerge in the model of Bourreau et al. (2011, 2014): One area where both firms have invested (so that there are two new networks besides the prevailing old one), one area where only the incumbent has invested (so that there is only one new network besides the prevailing old one) and one without any investment (so that there is only the prevailing old network). Accordingly, a high access price for the old network, which induces investment by the entrant, especially hampers static efficiency in the last-mentioned area, where investment is uneconomical. The high access price is passed on to the consumers and they have to pay high retail prices without having the possibility to get enhanced services.

Hence, in order to relieve this tension Bourreau et al. (2014) suggest to introduce geographically differentiated access prices for the old network. The regulator could increase consumer welfare by

[7] In their setting, Brito et al. (2012) assume that the entrant cannot invest and, therefore, rule out the possibility of facility-based competition. The situation of an incumbent investing first and considering whether he would deliberately grant access to his new network while acknowledging that the entrant might eventually invest has (to the author's knowledge) not yet been treated in the literature. It is imaginable that the incumbent might grant access to his new network at slightly beneficiary access terms in order to delay the entrant's investment and, thus, also the more severe facility-based competition.

setting ex-ante a cost-based access price in areas without new infrastructure. Yet, by committing to apply an above-cost access price in the remaining areas, where new infrastructure will have been rolled out, he could warrant investment by both the incumbent and the entrant. Since these access prices are set ex-ante for the old network and the new network is not regulated, the incumbent would expect a higher return on his investment. And the entrant might find it unattractive to continue to seek access to the old network at such terms and rather invest itself where feasible. Then, the only drawback concerns reduced static efficiency in areas where only the incumbent will have invested and the entrant keeps seeking access to the old network. In areas where both will have invested, however, facility-based competition emerges. (Bourreau et al., 2014)

3.3.4.2 The new infrastructure is subject to access regulation

Access regulation of the new infrastructure alters the firms' investment incentives. The prospect of mandated access at a low access price reduces the investment by the follower as it might find it more profitable to seek access instead of bearing high investment costs. The investing firm, however, anticipates a lower return (or even the impossibility of recovering its investment costs when the new access price is set at marginal costs) and thus also reduces its investment. A high access price, in contrast, can trigger more investment, since the investing firm gets an additional incentive in the form of a higher return when other firms seek access to its new infrastructure. Moreover, potential access-seeking firms might also decide to rather build their own alternative infrastructure as access-seeking is then less attractive. (Bourreau et al., 2011)

Interrelation of access prices

Bourreau et al. (2011) stress that there is an interrelation between the access prices for the old and the new infrastructure, which the regulator should account for. If the regulator has set a high access price for the old network in order to enforce more investment by the entrant (i.e. lowering its opportunity costs of investing), setting a low access price for the new network would counteract this aim. The entrant is then tempted to avoid paying a high access price for the old network and rather seek access to the new network instead of investing itself. (Bourreau et al., 2011)

However, a high access price for the old network is clearly accompanied by reduced static efficiency. To relieve this tension, the regulator could try to introduce more competition either by setting a lower access price for the old network or by inducing the emergence of alternative infrastructure. Lowering the access price for the old network indeed increases static efficiency but at the expense of dynamic efficiency. Less investment will occur and, hence, long-run consumer

welfare will be hampered.

Investment in better technology (which ultimately increases consumer welfare) can thus only be ensured by a high access price for the new network. Due to less attractive access terms, the entrant is more likely to invest. In addition, a high access price for the new network also warrants investment by the incumbent, which otherwise would be less likely. Especially in the case of high spill overs from the incumbent's investment, a low access price would challenge dynamic efficiency even more. Therefore, Bourreau et al. (2011) argue that both access prices should be positively correlated.[8]

Bourreau et al. (2011) state that this positive relationship might also be of importance if the regulator is more concerned about the migration from the old to the new network. A prevailing low access price for the old network should then be complemented by a low access price for the new network since otherwise consumers might find the new technology too expensive. Yet, investment incentives are reduced then.

In a successive study, Bourreau et al. (2014) note that switch-off obligations for the legacy network can force migration to the next generation network. This, in turn, gives the regulator more flexibility when setting the access price for the new network as he is no longer required to take into account the interrelation between both access prices.

[8] In Bourreau et al. (2011), this only applies if the incumbent is expected to have rolled out new infrastructure in more areas than the entrant. Otherwise, the relationship could possibly be negative. But this finding hinges on the assumption that the incumbent's investment is less responsive to the access price he would have to pay to access the entrant's new infrastructure. Hence, the regulator might rather set a lower access price in order to induce the incumbent to seek access, thereby increasing static efficiency on the new infrastructure. Yet, it is also questionable whether a situation in which the entrant has rolled out more infrastructure than the incumbent arises – given the cost advantage of the incumbent.

4 Empirical evidence

This section reviews important empirical studies. Each study is thereby described with respect to its country and time coverage, methodology and findings. The main focus is on the effects of access regulation on investment. In addition, the less numerous evidence regarding quality and retail prices is presented. Section 4.4 derives the consensus of these studies and provides a table that summarizes the main findings.

4.1 Effects on investment

Regarding the effects of access regulation on investment, the empirical literature either examines how broadband penetration is affected (thereby distinguishing between total and fiber lines), directly tests whether the ladder of investment theory holds, or studies how regulation generally affects investment.

4.1.1 Effects on broadband penetration

The empirical literature on the effects on broadband penetration investigates how access regulation affects the number of subscriptions to broadband services. Here, many studies look at the increase of total subscriptions, whereas some also examine the increase in alternative infrastructure lines. Moreover, these empirical studies differ in how they model access regulation. Some studies employ a measure of competition as the explanatory variable (Bouckaert et al., 2010; Briglauer, 2014; Briglauer et al., 2013; Cincera et al., 2012; Dauvin & Grzybowski, 2014; Distaso et al., 2006). Other studies use the level of the access price (Höffler, 2007; Waverman et al., 2007), a dummy variable for the introduction of local loop unbundling (LLU) (Gruber & Koutroumpis, 2013; Nardotto et al., 2012) or simply the number of unbundled lines (Wallsten & Hausladen, 2009; and the studies in section 4.1.2).

Regarding the findings, most studies show that only inter-platform competition triggers more total broadband penetration whereas intra-platform competition seems to have no effect. Yet, with respect to the LLU access price, the respective studies find that a lower access price leads to more total penetration. In addition, more unbundled lines negatively affect the number of fibre lines, whereas inter-platform competition has a positive effect on fibre deployment.

Additionally noteworthy are the following findings. Firstly, Wallsten and Hausladen (2009) find that incumbents employ more fibre lines with the presence of more cable lines. Entrants, in contrast, do not. Rather, especially entrants with own (old) facilities seem more likely to have more fibre lines.

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Secondly, the analysis of Waverman et al. (2007) indicates that, with a lower LLU access price, subscribers seem to be attracted away from alternative infrastructure to the DSL network. A related result is provided by Briglauer et al. (2013) and Briglauer (2014) who find that competition from cable leads to more investment in fibre but also that cable and DSL hamper subscriptions to fibre. Thirdly, Gruber and Koutroumpis (2013), who look at the speed of total broadband penetration, find that intra-platform competition has an accelerating effect whereas inter-platform competition has not. And fourthly, Dauvin and Grzybowski (2014) show that with a higher incumbent's share in DSL connections total broadband penetration seems to be lower. These studies are reviewed in the following.

The effect on total broadband penetration

Bouckaert et al. (2010) study the effect of competition on total broadband penetration in 20 OECD countries from 2003 to 2008. They differentiate between inter-platform competition from alternative infrastructure (cable and fibre) and intra-platform competition, which comes from entrants that either seek access via LLU or bitstream. For each form of competition, they employ the Herfindahl concentration index, whose effect on the total number of broadband connections as a share of the number of households is then estimated. In their analysis, they account for dynamics as well as for country and market specifics. They also address the endogeneity issue of the concentration index.[9] They find that only inter-platform competition triggers more broadband penetration. In contrast, intra-platform competition via LLU and via bitstream access show no significant effect on broadband penetration.

Cincera et al. (2012) also analyse the effect of competition on total broadband penetration in 18 European countries from 2003 to 2010. They distinguish between intra- and inter-platform competition, which they measure as the respective market shares. For the latter, they also differentiate between competition from alternative DSL lines and from other technology in general (i.e. an aggregation of fibre, cable and wireless technology). In their analysis, they address endogeneity and account for country specifics but not for dynamics. They find that intra-platform

[9] The question of interest is whether more competition leads to more broadband penetration. A highly concentrated market, which is mainly served by one firm, implies little competition. It could therefore expose low penetration. However, if the firm is really efficient, there could also be high penetration. A simple OLS regression would then underestimate the effect of the Herfindahl index on penetration (Bouckaert et al., 2010). It is possible to account for this issue by employing e.g. instrument variables or country fixed effects, which filter out the persistently efficient firm.

competition has no significant effect on broadband penetration, whereas inter-platform competition (in both forms) positively affects it.

Dauvin and Grzybowski (2014) study the effect of competition on total broadband penetration as well. Yet, in contrast to other studies, they do not rely on country-level data but rather employ regional data for the EU27 Member States from 2006 to 2010. They measure inter-platform competition using the Herfindahl concentration index, which they, however, construct from (subjective) household survey data. In addition, by doing so, they do not distinguish the different origins (fibre, cable, mobile). They further employ the LLU access price as an explanatory variable. In their analysis, they address endogeneity and account for country specifics but not for dynamics. They find that inter-platform competition has a positive effect on total broadband penetration. Moreover, in countries with a higher DSL share total broadband penetration is lower, whereas in countries with a higher cable share penetration is higher. The LLU access price exhibits a negative effect on penetration, i.e. a lower price is able to increase penetration. Furthermore, they also examine the impact of the incumbent's share in DSL connections finding that a greater share negatively affects penetration.

Distaso et al. (2006) also investigate the effect of competition on total broadband penetration using data of 14 European countries from 2000 to 2004. They measure penetration as the number of broadband lines as a share of total access lines (rather than looking at the share of total households). Competition is captured by the Herfindahl concentration index. In their analysis, they account for country specifics and the endogeneity of variables. They find that only inter-platform competition triggers more broadband penetration. In contrast, intra-platform competition shows no significant effect on broadband penetration. They also analyse the effect of access pricing and show that both prices for LLU access and bitstream access negatively affect penetration, i.e. a lower access price leads to more penetration.

Höffler (2007) examines the effect of the LLU on total broadband penetration employing data of 16 western European countries from 2000 to 2004. For this, he studies how the level of the access price affects the number of broadband subscribers as a share of the number of households. Thereby, he controls for dynamics, cable and the endogeneity of variables. He finds that inter-platform competition from cable has a significantly positive effect on broadband penetration. In contrast, the level of the access price has a significantly negative impact on penetration, i.e. with a lower LLU access price penetration increases.

Nardotto et al. (2012) analyse the effect of LLU access on total broadband penetration focusing specifically on UK data from 2005 to 2009. Accounting for dynamics and controlling for the presence of cable competition, they study whether the introduction of LLU increases the total number of broadband subscribers as a share of total telephone lines at a local exchange. They find that unbundling has a slightly negative effect on broadband penetration compared to areas where the local loops are not unbundled. Yet, unbundling reduces the share of bitstream access. In contrast, inter-platform competition from cable significantly increases broadband penetration.

Gruber and Koutroumpis (2013) employ a large dataset of 167 countries from 2000 to 2010 in order to study how access regulation affects the speed of total broadband penetration. In other words, they investigate growth rates in contrast to the previous studies, which rather specifically look at the increase in the absolute number of total broadband lines. Accounting for dynamics, country specifics and a possible endogeneity of variables, they find that the introduction of LLU catalyses broadband penetration. However, the effect seems to abate after three years. The introduction of retail unbundling (i.e. bitstream and resale access) exposes an even stronger and longer lasting effect on the diffusion speed. Hence, intra-platform competition accelerates broadband penetration. Inter-platform competition, in contrast, seems to negatively affect the speed of broadband penetration. (The intensity of competition on the cable infrastructure has no significant effect.)

These findings seem to counter the results of previous studies, which find that only inter-platform competition increases penetration. Yet, as already mentioned, those studies look at the increase in broadband lines. Comparability is therefore not given. Fortunately, Gruber and Koutroumpis (2013) provide an additional analysis focusing on the increase in broadband lines. The respective results confirm the accelerating effect of both unbundling regulations (yet, at a lower strength) but do not show a significant negative effect of inter-platform competition on penetration anymore. That is, inter-platform competition does not hamper broadband penetration; it rather does not seem to affect it. (However, the large coverage of countries might also bias the comparability to the previous Europe-centered studies.)

The effect on fibre deployment

Briglauer et al. (2013) analyse the effect of competition on investment in fibre lines in the EU27 Member States from 2005 to 2011. In their study, they are interested in the increase in fibre lines (which reach to consumers but need not be actively connected; the latter would correspond to a study of penetration). They distinguish between inter- and intra-platform competition, which they

measure as the respective market shares. That is, regarding inter-platform competition they account for cable and mobile connections respectively. On the other hand, regarding intra-platform competition, they employ the share of total regulated wholesale broadband lines, for which they, however, do not distinguish between full and bitstream unbundling. They account for dynamics as well as for country and market specifics and address endogeneity. Their results show that intra-platform competition has a negative impact on fibre deployment. Inter-platform competition from cable and mobile, in contrast, exhibits a positive effect, respectively. They state that these positive effects appear in the shape of an inverted U, which means that up to a certain point more inter-platform competition increases fibre deployment, but after this point, more competition has an abating effect.

Briglauer (2014) studies the determinants of fibre penetration for the EU27 Member States from 2004 to 2012. In contrast, to his preceding study (Briglauer et al., 2013), he looks at the increase of fibre lines that are actively connected to the households. In his analysis, he distinguishes between intra- and inter-platform competition, also measured by market shares. He further addresses endogeneity and accounts for dynamics as well as for country and market specifics. His results indicate that more intra-platform competition negatively affects fibre deployment. In contrast, inter-platform competition (which he processes solely as from mobile technologies) exposes a positive effect on fiber penetration. In line with his earlier study (Briglauer et al., 2013), he finds a non-linear, inverted U-shaped relation. Moreover, his modelling enables him to analyse whether a more well-established prevailing infrastructure hampers fiber deployment, which it does. Interestingly, he does not find any difference between a prevailing DSL or cable network and concludes that both seem to equally hamper fiber deployment.

Wallsten and Hausladen (2009) investigate how fiber broadband penetration is affected by unbundled lines. In their analysis, they also look at the effects on other alternative infrastructure and distinguish between incumbent and entrants. They employ data of 27 European countries from 2002 to 2007, thereby accounting for country specifics but not for dynamics. Yet, their only control variable is (country) income. They find that the numbers of LLU lines as well as of bitstream access lines negatively affect the number of fiber lines of incumbents and entrants, respectively. In addition, the number of LLU lines also has a negative impact on cable lines and on DSL connections provided over entrants' own facilities. However, the number of lines characterized by bitstream access does not show a significant effect on these lines. Moreover, Wallsten and Hausladen (2009) show that the

incumbents' number of fiber lines is positively affected by the number of cable lines. In contrast, the entrants' number of fiber lines does not seem to respond to cable. It is rather positively related to the number of DSL connections provided over entrants' own facilities, i.e. entrants that provide service over their own infrastructure are more likely to invest in fiber.

Waverman et al. (2007) examine the effect of the LLU access price on the share of alternative infrastructure employing data of 12 European countries from 2002 to 2006. They measure the share of alternative infrastructure (which includes fiber as well as cable without distinction) as the number of subscribers using these lines relative to the number of total lines. In their econometric analysis, they address the endogeneity of variables, control for cable and account for dynamics but not for country specifics. They find that a lower LLU access price reduces the subscriber share of alternative infrastructure (while increasing the share of entrants' LLU access lines), i.e. the increased competition on the prevailing DSL infrastructure leads to a substitution of subscribers away from alternative infrastructure to DSL. Yet, their measure for alternative infrastructure mainly comprises cable, and no analysis is undertaken to see whether cable or fiber is more affected from this substitution. In addition, they state that this enhanced intra-platform competition potentially reduces investment in alternative infrastructure by both incumbents and entrants.

4.1.2 Testing the ladder of investment theory

Only few empirical studies exist that directly test the ladder of investment hypothesis. The most recent one is by Bacache et al. (2014), who find no empirical support that entrants invest in their own next generation infrastructure. The results of Hazlett and Bazelon (2005) and of Crandall and Sidak (2007) also challenge the ladder of investment theory, but their empirical analyses are rather less sophisticated and employ older data.

Bacache et al. (2014) test the ladder of investment hypothesis using data of 15 European countries from 2002 to 2010. They examine whether the total number of service-based (unbundled) lines in previous periods can explain the total number of facility-based lines (of new (non-DSL, non-cable) technology) owned by new entrants. They account for country specifics, for general shifts in demand and costs as well as for cable competition. They find no empirical support for the transition from LLU to new infrastructures by entrants. Yet, they find weak empirical support for the transition from bitstream access lines to LLU. That is, entrants seem to climb up the ladder but are stuck at the last rung.

In addition, Bacache et al. (2014) observe that, in countries with a high penetration of cable, the number of LLU lines negatively affects the number of entrants' new lines so that the ladder of investment is even less effective in such countries. In countries with low cable penetration, in contrast, entrants do not seem to move from bitstream access lines to LLU.

Hazlett and Bazelon (2005) also test the ladder of investment hypothesis. Yet, their evidence is rather old as they employ US data from 1999 to 2004. They also examine whether the share of LLU lines in previous periods affects the share of facility-based lines owned by entrants. They find no statistical support for it and reject the hypothesis. Yet, their econometric analysis can be questioned as they only employ weak control variables (only the unemployment rate). Cave (2006) argues that their evidence rather shows the failure to correctly apply the ladder of investment approach, which could be attributed to too cheap access terms.

Further evidence against the ladder of investment hypothesis is provided by Crandall and Sidak (2007). Yet, they do not provide an econometric analysis. They rather examine for 15 European countries over the period from 2002 to 2006 whether the share of entrants' LLU lines on their total lines has increased and overtook the sum of their bitstream lines. In terms of the ladder of investment theory, they are interested whether entrants have climbed up to the LLU rung. However, they do not study whether entrants have invested in own infrastructure (as the next step on the ladder). They find that only two of the 15 countries provide support for ladder of investment hypothesis. These comprise France and Italy, two countries with little or no cable competition as they point out.

In addition, although the afore-mentioned study by Wallsten and Hausladen (2009) does not explicitly test the ladder of investment theory, its findings also enable an assessment of this hypothesis. To recap, they find that the number of LLU lines has a negative impact on DSL connections provided over entrants' own facilities whereas the number of bitstream access lines has not. Moreover, they find that the numbers of LLU lines as well as of bitstream access lines negatively affect the number of fiber lines of entrants. This implies that entrants also seem to be stuck at the last rung and invest neither in their own bypassing DSL nor fiber infrastructure. Yet, they also show that entrants that provide service over their own infrastructure are more likely to invest in fiber. That is, once entrants have climbed the last rung, they also more easily adopt new technologies.

4.1.3 Effects of regulation in general on investment

There also exists literature dealing with the impact of regulation on investment. The following studies have in common that they rely on an index as a measure for regulatory intensity, which is intended to serve as a proxy for competition. On the one hand, the intensity of regulation thus becomes comparable between countries. But, on the other hand, it then precludes assigning the estimated effects to a specific regulation (like e.g. whether there is LLU). That is, rather the effectiveness of regulation in general is assessed.

Interestingly, the empirical literature is not only ambiguous regarding the impact of regulation on investment. But the result also depends on the addressee of the study. Friederiszick et al. (2008) and Grajek and Röller (2012) have received funding from the German incumbent Deutsche Telekom and find a negative relationship. London Economics and PricewaterhouseCoopers (2006), who prepared their report for the European Commission, and the report of Cadman (2007) for the European Competitive Telecoms Association (ECTA) find a positive relationship. Yet, it is to mention that the results of the latter two studies are based on a weak econometric analysis.

Friederiszick et al. (2008) analyse the relationship between regulatory intensity and investment using data of 25 European countries from 1997 to 2006. They employ the Plaut Economics regulatory index to measure access regulation independently of country-specific costs. In order to quantify investment, they draw on figures of tangible fixed assets. Yet, their figures do not cover investment in next generation infrastructure. In their analysis, they account for dynamics, country and market specifics, cable as well as for the endogeneity of regulation. They find that access regulation significantly discourages investment in fixed-lines by entrants. In contrast, there does not seem to be a significant effect on the incumbent's investment.

In kind of subsequent study, Grajek and Röller (2012) confirm the previous findings and elaborate more on the response of regulation to investment. They use firm-level data on tangible fixed assets for 20 European countries from 1997 to 2006, and employ the Plaut Economics regulatory index. They also account for dynamics, country specifics, and cable as well as for the endogeneity of regulation. However, like in Friederiszick et al. (2008), their data does not cover investment in next generation networks. Their results show that access regulation significantly discourages individual investment by entrants and incumbents, even though the entrants' total investment increases. In addition, they find that regulation seems to toughen in response to more investment by incumbents but not by entrants.

London Economics and PricewaterhouseCoopers (2006) also study the relationship between regulation and investment. For the years 2001 to 2004, they have collected data on investment in tangible assets from company annual reports for 25 European countries, which they claim to be congruent with official aggregate data. From a regression of investment on the OECD regulatory index (a measure for regulatory performance), they conclude that a better performing regulatory regime contributes to higher investment. Yet, the empirical estimate is not statistically significant, and even though they account for country specifics, they disregard dynamics or the endogeneity of regulation. Also with respect to the fragile data-gathering, this conclusion does not seem to be credible.

Cadman (2007) also claims to find a positive relationship between regulation and investment. He employs data for 16 European countries in 2003 and 2005. However, he relies on figures of total investment by all operators in any form (i.e. regardless of tangible/intangible assets or fixed/mobile network). As a measure for regulatory intensity, he draws on the OECD regulatory index and on the ECTA scoreboard, respectively. In contrast to the other mentioned studies, he does not employ a time series analysis but only examines both years separately. He finds that better regulation promotes more investment. Yet, the results are not credible since the employed sample is very small, the econometric analysis is less sophisticated, no dynamics are considered and highly aggregated figures are used.

4.2 Effects on retail prices

Studies that provide empirical evidence about the effect of access regulation on quality are not as numerous as those focusing on investment/penetration. However, the existing studies employ recent data and indicate that LLU drives down retail prices. The effect of inter-platform competition is less clear: Either it has no effect or it also leads to lower retail prices.

Calzada and Martínez (2013) analyse the determinants of broadband prices for 15 EU countries between 2008 and 2011 using data at the firm level and controlling for country specifics. In general, they show that higher speed leads to higher retail prices and that incumbents set their prices higher than competitors. Yet, alternative technology (i.e. fiber and cable) exposes lower prices per Mbps than DSL. With respect to access regulation, they find that retail prices are higher in countries where entrants rely more on bitstream access and lower when they seek access via LLU. In addition, they show that if an entrant has invested in own infrastructure, it does not charge significantly higher retail

prices. Neither do they observe any effect of inter-platform competition (from fiber or cable) on retail prices. This implies, in combination with the finding that these alternative technologies are characterized by lower prices per Mbps, that alternative infrastructures are able to provide improved services at a comparable price to DSL and do not charge consumers at extra cost.

In a report for the European Commission, Ecorys (2013) also analyse the effect of LLU access on retail prices. They use data of 27 European countries from 2003 to 2011. Prices are captured by the average revenue per user, and LLU is modelled as the market share of LLU connections on the total number of broadband connections. In their analysis, they account for cable and for country specifics (and thus also for the endogeneity of the market concentration measure). They find that an increased market share of LLU connections significantly reduces retail prices. In addition, a greater market share of cable operators is also related to lower retail prices.

Smith et al. (2013) examine the effect of competition on broadband prices. They employ data on retail prices for the EU27 Member States from 2008 to 2011. They distinguish between intra-platform (which is measured as the share of LLU and bitstream access lines to total broadband lines) and inter-platform competition (which is measured as the share of entrants' non-DSL lines to total broadband lines, thus including cable, fiber and mobile). They use some control variables to account for bundled services and (country) income but they do not account for country specifics or dynamics. Their results show that inter-platform competition and a larger share of LLU reduce retail prices, respectively. (This contrasts the finding of Calzada and Martínez (2013) that inter-platform competition has no significant effect.) Inter-platform competition exhibits a larger effect. In contrast, bitstream access leads to higher prices.

Fageda et al. (2014) also examine the effect of competition on broadband prices, but they focus specifically on Spain from 2005 to 2011. They employ data on the broadband access tariffs offered by Spanish telecom operators, thereby distinguishing between the lowest possible price and the price for the most popular service of the respective operator. They differentiate between intra-platform and inter-platform competition, which they respectively measure as the share of entrants' DSL lines to the incumbent's DSL lines and as the share of cable lines to total DSL lines. In their analysis, they control for speed, for bitstream access as well as for the scale effects of big operators and for dynamics. Their results indicate that inter-platform competition has no effect, whereas intra-platform competition reduces broadband prices. In addition, they show that entrants that seek bitstream access charge higher retail prices. Larger operators also seem to set higher prices. They

ascribe their results to the weak competitiveness of the Spanish cable network. In Spain, television is mainly transmitted via radio waves, thus entailing a low development of the cable network.

4.3 Effects on quality

In the aforementioned study by Nardotto et al. (2012), the authors also investigate the effect of LLU access on download speeds. They find that unbundling increases the average broadband speed. This can be entirely attributed to entrants. The speed on the incumbent's lines has not significantly altered. In contrast, the download speed on bitstream lines is significantly lower than on the incumbent's lines. Cable subscribers, however, experience a higher download speed than DSL subscribers.

The effect of competition on broadband speeds is also analysed in the previously described study by Smith et al. (2013). Like Nardotto et al. (2012), they focus on actually measured download speed rates instead of advertised ones. Their results indicate that inter-platform competition and LLU can increase broadband speeds. In contrast, bitstream access leads to lower speeds.

4.4 Consensus of findings

The previous review of the numerous empirical studies has revealed that they do not only differ in their coverage but also in their econometric approach. Yet, an in-depth assessment of the credibility of these studies is not the purpose of this review, which also seems less essential as their findings are quite consistent (see below). Whether these studies include important properties is, however, covered in the respective descriptions. These include especially whether the studies account for the endogeneity of competition measures (see footnote 9), for dynamics (i.e. considering that e.g. unbundling might only develop its effect in the following period) and for country specifics (i.e. using a fixed-effects regression in order to control for time-indifferent variances among countries, whose non-consideration would otherwise bias the estimates if any unobserved country specifics also explain the dependent variable). In general, the reviewed studies are based on acceptable econometric frameworks. Often, they also address possible drawbacks directly in their analyses. Any reservation which, however, remained has been addressed in the respective description of study in the previous review.

Table **1** summarizes the main findings with respect to broadband penetration, the ladder of investment, quality and prices in order to keep an overview of the numerous studies. The results regarding the effect of general regulation on investment are not reported in the table. Since the praticular studies employ an index to measure the regulatory intensity, they are unable to number the effect of any individual regulatory measure like e.g. unbundling, which, however, is the main focus of the study at hand.

Regarding the main findings of the reviewed studies, it is to acknowledge that, despite their technical variety, they seem to agree on the following. The number of total broadband lines is only significantly increased by inter-platform (i.e. facility-based) competition. Intra-platform (i.e. service-based) competition seems to have no or only a temporary effect. Yet, when the situation of intra-platform is considered more in detail, a lower LLU access price can also trigger more total broadband penetration. In addition, regarding fiber penetration intra-platform competition has a negative effect on it, whereas inter-platform competition positively affects it. Though, it is noticed that competition from cable indeed can trigger more investment in fiber lines (Briglauer, 2014), but this does not ensure that consumers also switch to it (Briglauer et al., 2013; Waverman et al., 2007).

Moreover, LLU leads to a reduction in retail prices, and increases quality (i.e. download speeds). Competition from alternative technologies also tends to reduce retail prices. But the empirical evidence in this regard is not clear. At least it can be stated that broadband services provided by alternative infrastructures do not seem to expose higher prices than DSL services.

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Table 1: Summary of the main findings of the empirical studies

The effect of [insert heading of column 4-6] on total broadband penetration

Study	*Countries*	*Time period*	*Inter-platform competition*	*Intra-platform competition*	*LLU access price*	*Remarks*
Bouckaert et al. (2010)	20 OECD countries	2003 - 2008	positive	insignificant	n/a	Competition measured by HHI; account for dynamics, country specifics and endogeneity
Cincera et al. (2012)	18 EU countries	2003 - 2010	positive	insignificant	n/a	Competition measured by market shares; account for country specifics and endogeneity
Dauvin and Grzybowski (2014)	27 EU countries	2006 - 2010	positive	n/a	negative *	Use regional data; competition measured by HHI (yet, rather general measure and based on survey, thus more dubious); account for country specifics and endogeneity
Distaso et al. (2006)	14 EU countries	2000 - 2004	positive	insignificant	negative *	Competition measured by HHI; account for country specifics and endogeneity
Höffler (2007)	16 EU countries	2000 - 2004	positive	n/a	negative *	Competition measured by market shares; accounts for dynamics and endogeneity
Nardotto et al. (2012)	United Kingdom	2005 - 2009	positive	slightly negative	n/a	Use data at local exchange (LE) level, hence unbundling measured by dummy and cable by share at LE; control for dynamics
Gruber and Koutroumpis (2013)	167 countries	2000 - 2010	insignificant	slightly positive	n/a	Results reported here are for increase in lines not for diffusion speed; competition measured by HHI; account for dynamics, country specifics and endogeneity; results should be treated carefully due to large country sample

* i.e. a lower access price leads to more penetration

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Table 1: Summary of the main findings of the empirical studies (continued)

The effect of [insert heading of column 4-6] on fiber deployment

Study	*Countries*	*Time period*	*Inter-platform competition*	*Intra-platform competition*	*LLU access price*	*Remarks*
Briglauer et al. (2013)	27 EU countries	2005 - 2011	positive	negative	n/a	Results reported here are for fiber investment not penetration; competition measured by market shares; account for country specifics and endogeneity
Briglauer (2014)	27 EU countries	2004 - 2012	positive for mobile, negative for cable	negative	n/a	Competition measured by market shares; accounts for country specifics and endogeneity
Wallsten and Hausladen (2009)	27 EU countries	2002 - 2007	positive on incumbent, insignificant on entrant	negative	n/a	Simply regress number of lines of interest on fiber lines accounting only for country specifics; thus results should be treated carefully
Waverman et al. (2007)	12 EU countries	2002 - 2006	n/a	n/a	positive (i.e. if lower, users switch to DSL)	Capture effect on fiber and cable together; account for dynamics and endogeneity

Ladder of investment: Transition from [insert heading of column 4-5] is supported?

Study	*Countries*	*Time period*	*LLU to own infrastructure*	*Bitstream access to LLU*	*Remarks*
Bacache et al. (2014)	15 EU countries	2002 - 2010	no	yes	Entrants' own infrastructure measured only as of new technology; account for country specifics, dynamics and cable competition
Hazlett and Bazelon (2005)	United States	1999 - 2004	no	n/a	Entrants' own infrastructure measured technological-neutrally, yet weak econometric framework
Crandall and Sidak (2007)	15 EU countries	2002 - 2006	n/a	positive for only two countries	Their analysis only relies on a qualitative assessment by country
Wallsten and Hausladen (2009)	27 EU countries	2002 - 2007	no	n/a	See above; reported results are based on an interpretation of their initial findings

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Table 1: Summary of the main findings of the empirical studies (continued)

The effect of [insert heading of column 4-6] on retail prices

Study	*Countries*	*Time period*	*Inter-platform competition*	*LLU access*	*Bitstream access*	*Remarks*
Calzada and Martínez (2013)	15 EU countries	2008 - 2011	insignificant	negative **	positive **	Competition measured by market shares; account for bundled services, endogeneity, country specifics
Ecorys (2013)	27 EU countries	2003 - 2011	negative **	negative **	n/a	Competition measured by market shares; account for country specifics and endogeneity
Smith et al. (2013)	27 EU countries	2008 - 2011	negative **	negative **	positive **	Competition measured by market shares; account for bundled services
Fageda et al. (2014)	Spain	2005 - 2011	insignificant	negative **	positive **	Competition measured by market shares; account for dynamics

** for interpretation: negative implies that prices are reduced, vice versa for positive

The effect of [insert heading of column 4-6] on download speeds

Study	*Countries*	*Time period*	*Inter-platform competition*	*LLU access*	*Bitstream access*	*Remarks*
Nardotto et al. (2012)	United Kingdom	2005 - 2009	higher speeds for cable users	positive on entrants, insignificant on incumbents	negative	See above; use actually measured download speeds
Smith et al. (2013)	27 EU countries	2008 - 2011	positive	positive	negative	See above; use actually measured download speeds

5 Implications for an optimal access pricing policy

This section processes the findings of the theoretical and empirical studies. For this, it conceives two scenarios, which differ in the underlying regulatory policy goals. In order to meet these goals, an optimal access pricing policy is respectively derived for each scenario. In addition, the impact of the particular access prices on investment is described. However, both initial scenarios are independent of the existence of a competing cable network owing to the fact that the previously treated theoretical literature abstracts from it. Yet, section 6 will elaborate more on this subject through an extension of the two scenarios to a situation in which a competing cable network is present, as in the Dutch case.

In the first scenario, the regulator presumes that there is no business case for a replication of the last mile infrastructure. The regulator is assumed to have a preference for high consumer welfare in the short run rather than in the long run (i.e. he prefers static over dynamic efficiency). Accordingly, he rather strives for service-based competition anticipating a reduction in retail prices. The motivation for this policy goal stems from the empirical failure of the ladder of investment hypothesis showing that LLU does not lead to investment in bypassing infrastructure by entrants. The scenario further employs the empirical observations that a low access price triggers more broadband penetration and that LLU entails lower retail prices.

In the second scenario, the regulator rather wants to ensure high consumer welfare in the long run. Thus, he definitely aims for a replication of the last mile infrastructure by entrants, for which he assumes that a business case exists. In general, this replication could be technology-neutral, but it is recognized that investment will rather occur in infrastructure of enhanced quality as this gives the investor a competitive edge. This policy goal is also motivated from the empirical evidence. It is acknowledged that LLU has not yet led to particular investment in alternative last mile infrastructure. That the ladder of investment hypothesis seems to fail is in this scenario not attributed to non-feasibility but rather ascribed to an inaccurate or incomplete implementation. In addition, the regulator also strives for facility-based competition because he supposes that it will entail the same benefits to consumers as the empirical evidence indicates for inter-platform competition from cable. This means, that the presence of an additional network might also lead to more broadband penetration, lower retail prices and higher quality. Consumers would thus additionally benefit from a higher variety of services. Importantly, it is to keep in mind that there initially exists only the incumbent's last mile infrastructure in this scenario. Employing empirical evidence regarding the effects of cable competition only serves as a figuratively justification.

5.1 Scenario 1: Promoting service-based competition

Given that the access price is likely to be passed on to the consumers, any access price set higher than the marginal costs of providing access will distort retail prices and will reduce current consumer welfare. Setting the access price equal to marginal costs will thus ensure a maximization of static efficiency thereby triggering the entry of cost-efficient firms. This promotes service-based competition with downward-pressure on retail prices. Setting the access price even lower might further increase consumer welfare but would also result in the entry of less efficient firms. (See section 2.2)

Yet, an access price set at marginal costs does not account for the fixed costs of infrastructure. Thus, a regulator might want to compensate the incumbent for the incurred investment costs. However, knowing that any increase in the access price is at the expense of consumer welfare, the regulator might be, at most, willing to mandate a cost-based access price[10]. In the strict sense, this reduces static efficiency to some extent compared to the situation with an access price set at marginal costs. But this will still ensure entry and downward-pressure on retail prices. This is supported by the empirical evidence: A lower LLU access price leads, on the one hand, to more penetration and, on the other hand, to less concentrated markets (Bouckaert et al., 2010). Via an increased intra-platform competition, it also entails lower retail prices. (See sections 4.1.1 and 4.2)

Implications for investment

As a next step, it is interesting to see how such a cost-based access price affects the investment decisions of both the incumbent and entrants.

Trivially, since the access price is not set above costs, the incumbent will not receive any surplus from access charges and is, at most, compensated for his incurred investment costs. The incumbent might then only engage in investment, if this is more beneficial to him than to the entrants. Thus, he could invest in cost reductions in order to get a competitive advantage over his competitors. However, any investment that also benefits the access-seeking entrants is less likely because helping his competitors would imply to possibly lose customers to them. Compared to an unregulated setting, he would invest less in quality upgrades as he is not able to freely set an access price in order to absorb profits from the benefitting entrants. If the entrants' ability to provide better services when using an upgraded infrastructure is greater than the incumbent's ability, his investment is even

[10] In order to avoid confusion, when speaking of a cost-based access price, an access price is meant which at least accounts for the investment costs. Beyond that, it could also correct for asymmetric risk, technological change or the cost of equity as elaborated on in section 3.1. In contrast, when speaking of an above-cost access price, this level is even deliberately exceeded in order to actively provide investment incentives.

more unlikely. The reason is that the incumbent would then help cannibalize himself by losing customers to the entrants. In addition, if the design of the cost-based access price also fails to account for the asymmetrically more borne risk or the increased cost of capital of the incumbent, his incentives to invest are also hampered. (See sections 3.1 and 3.3.1)

Regarding entrants, it seems quite obvious that investment in a bypassing infrastructure is unlikely as the regulator already has presumed that there might not be a business case for it. Still, it is important to explain the underlying mechanism. A cost-based access price triggers entry by cost-efficient firms. Relying on the incumbent's last mile infrastructure, they provide services to consumers as long as they operate profitably. With the rather low access price, an entrant then faces opportunity costs of investing: Investing would imply to forego these profits from access-seeking (i.e. the replacement effect, see section 3.3.2). The lower the level of the cost-based access price, the more profitable could access-seeking turn out, thus making investment less likely. Yet, if the regulator falsely supposed the absence of a business case, an entrant, which has used the period of access seeking to build up reputation and a customer base, could always decide to invest in its own infrastructure in order to provide higher quality services to its consumers. Yet, the access price does not play a supportive role (as intended in this scenario) and might even hamper this – as suggested by the empirical evidence: Being less able to charge higher retail prices for services on a next generation infrastructure as consumers are used to low retail prices for lower quality, causes lower returns of own investment which makes access-seeking more attractive.

Regulation of new infrastructure

Even in this scenario, the regulator also has to deal with the possible situation in which alternative, next generation infrastructure emerges although the roll-out has not been actively promoted by the regulated access price. He has to take the presence of the new network as given, and has to decide how to regulate it in order to enhance static efficiency. The empirical evidence indicates that a low access price for the legacy network hampers the migration of consumers to the next generation infrastructure (Briglauer et al., 2013; Waverman et al., 2007). That is, consumers rely on lower quality broadband services at low retail prices and are less likely to switch to the more expensive new network. Accordingly, there is scope to increase current consumer welfare.

For his access pricing decision, the regulator should consider that the access price for the old and new infrastructure should be positively correlated (Bourreau et al., 2011, 2014). That is, given that the access price for the old network is low, i.e. on a cost-based level, the one for the new network should also be cost-based in order to introduce service-competition and to finally reduce

retail prices. With a resulting, decreased price differential, consumers might find it easier to switch. However, if the regulator is mainly concerned about migration, and wants to make consumers switch as soon as possible, he could also consider switch-off obligations of the legacy network as proposed by Bourreau et al. (2014). (See section 3.3.4.2)

Again, it is interesting to see how a cost-based access price for the new network affects investment. The prospect of being mandated to provide access at such terms to entrants hampers investment in new infrastructure in the first place. Service-based competition would emerge and the investor would face a reduced return of investment due to decreased retail profits. Besides, a cost-based access price, which does not account for e.g. the asymmetric risk of investment, hinders investment. Moreover, investment by entrants is unlikely as well since the possibility of access-seeking seems far more attractive than investing themselves. (See section 3.3.4.2)

Could the regulator in this scenario be tempted to leave the new infrastructure unregulated in order not to distort investment decisions? The investor might then invest since the return on investment is not reduced by a low access price or increased competition. It might accordingly set monopolistic retail prices, and probably foreclose competitors. Yet, it could also be possible that it voluntarily grants access to competitors if the old network still exposes strong competition to the new network, i.e. if consumers are used to low retail prices and are thus less likely to switch. Granting access could then entail that the entrants migrate their consumers to the new network. Yet, the incumbent would then stipulate an access price to absorb profits from the entrants (see section 3.3.4.1). All in all, this is clearly at the expense of static efficiency on the new network. Being interested in enhanced static efficiency, the regulator would, therefore, mandate a cost-based access price also for the new network.

In conclusion, the policy goal of this scenario, to promote service-based competition, can be reached by mandating a cost-based access price for the old and the new network. However, dynamic efficiency is then traded off for static efficiency. Investment by entrants in bypassing infrastructure is indeed not anticipated in this scenario, but the incumbent's incentives to upgrade his prevailing infrastructure or to invest in next generation infrastructure are also kept low.

5.2 Scenario 2: Promoting facility-based competition

When striving for facility-based competition, it is not conducive to set the access price for the prevailing infrastructure too high or too low. An access price set very high with the aim to force entrants to directly invest in bypassing infrastructure (and thus preventing them to seek access) implies that entry with the help of an own infrastructure will only take place once an entrant's

consideration of costs and benefits indicates to break even. On the one hand, such an access price ensures to avoid any delays resulting from artificially lowered opportunity costs of investment for the entrants (i.e. alleviating the replacement effect). Yet, on the other hand, this also implies a prolonged period without any (service-based) competition and thus decreased consumer welfare due to possible monopoly pricing of the incumbent. The incumbent could indeed not invest before facility-based competition finally occurs in order to receive monopoly profits as long as possible – given that his investment would make the entrants' investment more likely. This period lasts the longer the more expensive the investment is. Moreover, without the chance to seek access, the entrant could be unable to build up reputation. Thus, it might be less incentivized to invest when expecting a more difficult entry. (See section 3.3.2)

An access price that is set too low will, like in the first scenario, not incentivize an entrant to invest in bypassing infrastructure. Depicting the replacement effect, its opportunity costs of investing are kept at a high level: If it invests, it would forego any profits from access-seeking.

Thus, in order to induce investment by the entrant, the access price has to increase over time. In a similar vein to the ladder of investment (see section 3.3.2.1), setting a dynamically increasing above-cost access price will incentivize the entrant to climb on the next rung. Given the empirical observation that entrants currently seem stuck on the last rung (seeking LLU access), this would imply to build a bypassing last mile infrastructure as a next step. This results from two thoughts. First, the entrant's opportunity costs of investing decrease with each increase in access price, thereby making investment more likely (as the entrant encounters sequentially reduced profits from access-seeking, thus making it more unattractive). Second, with a given customer base, the entrant would unlikely pass further increases in access price to its customers. Any increase in retail price without any added value is hardly justifiable. The entrant might be able to cushion some initial increases while accepting some loss of profits. Yet, in the end, it will be forced to escape this dilemma by ideally investing in bypassing infrastructure.[11] This infrastructure might also be of enhanced quality in order to offer better service, which might be valued by consumers. Thus, the entrant would gain more price flexibility as its variable costs are no longer affected by access price payments.

[11] Alternatively, it might leave the market, thus putting the incumbent in a monopolistic position. Yet, since a business case for the replication of the last mile infrastructure is assumed in this scenario, this alternative is precluded.

Implications for investment

Here, too, the access-pricing policy in form of a dynamically above-cost access price affects investment. As just described, investment by entrants can actively be triggered. But how is the incumbent impacted?

The incumbent obviously benefits from higher access charge revenues (as long as the entrant seeks access). Of course, he might simply enjoy them. But he could also engage more in investment as these revenues give him the possibility to recover investment costs and to get additional rents. Thus, he might conduct cost reductions in order to get a cost advantage, which could attract customers away from the entrant. On the one hand, this implies a loss of access charge revenues. But, on the other hand, a higher customer base might be of his interest as he knows that he will eventually face facility-based competition (when the entrant has rolled out its bypassing infrastructure). Moreover, investments in quality upgrades might seem likely as any demand-increasing investment would also increase his profits from access charges. Yet, especially if the entrant disproportionately benefits from the incumbent's investment and thus attracts more consumers than the incumbent, such investment appears rather unlikely. The reason is, again, that the incumbent acknowledges to eventually face facility-based competition, and thus is less willing to support the entrant in getting a higher customer base. Therefore, his incentive to improve the quality of his infrastructure seems rather low. (See section 3.3.1)

With respect to investment in alternative, enhanced infrastructure, the incumbent might pre-empt its competitors by investing first. Moving first might result from access charge revenues from the old network, which give him some kind of a cost advantage, but he might also benefit from an information advantage. Yet, the incumbent's investment might be triggered strongest, if the new network remains unregulated. The prospect of being able to set monopoly prices enforces the pre-emption motive. This also holds for entrants so that both parties might engage in an investment race if they have equal investment costs (and funding). (See section 3.3.3.1)

However, if the incumbent's investment entails cost reduction for the entrant, this might hamper the incumbent's investment due to the wholesale revenue effect (Bourreau et al., 2011). An entrant might benefit from reduced administrative and contractual costs in areas where the incumbent has already invested. Investment by the entrant is then more likely, but also implies that it no longer pays access charges to the incumbent. However, since the access charge is initially high in this scenario, the incumbent then foregoes quite high access charge revenues. In addition, he even faces more severe facility-based competition. Therefore, the incumbent could also invest less in the first place. (See section 3.3.4.1)

Regulation of new infrastructure

Disregarding the possible wholesale revenue effect, would the regulator be in favour of leaving the next generation infrastructure unregulated? He might expect more investment by the incumbent since he can then set his own retail prices to make the investment pay off. Furthermore, the regulator might expect that the incumbent would not grant access to his infrastructure which, in turn, would incentivize the entrant to invest itself. Yet, the incumbent might exactly want to impede this occurrence of facility-based competition. For this, he might voluntarily grant access at favourable terms in order to delay the entrant's investment. In the end, this means that facility-based competition is unlikely to emerge. Since this contradicts the policy goal in this scenario, the regulator might rather decide to regulate the new network, thereby aiming to ensure the investment incentives of entrants.

A rather low access price for the new infrastructure would not be able to reach this goal, as even with a cost-based access price, access-seeking might appear more profitable to entrants than to invest themselves. Accordingly, the regulator might mandate an access price that is at least as high as the one for the old network. A high, above-costs access price would render access-seeking unattractive. In terms of the replacement effect, the entrant's decision to replicate the incumbent's infrastructure is then not delayed since it hardly faces any opportunity costs in terms of beneficial access-seeking. In general, the regulator might even impede access to the new infrastructure (by setting a prohibitively high access price) in order to induce the entrant to invest as soon as possible. By doing so, the regulator can prevent the incumbent from deliberately delaying the entrant's investments by voluntarily providing access at low terms. In an unregulated situation, the regulator would not have such a control. (See sections 3.2.3 and 3.3.4.2)

At this juncture, the crucial part is that, at the same time, the access price for the old network has to be increasing. This way, the entrant is not only prevented from access-seeking to the new network, but remaining on the last rung of the old network also becomes less and less attractive. As described above, the entrant might only escape this tension by investing itself in bypassing infrastructure.[12]

In addition, the incumbent's incentives to invest are warranted since the above-cost access prices promise some profits to the incumbent, i.e. the access prices do at least not minimize his return on investment. It is further of importance that the high access price for the old network provides some scope for the incumbent to set higher retail prices for services using the next generation

[12] Or by exiting the market. But since a business case is assumed, this alternative is precluded.

infrastructure as consumers are not used to low retail prices for services of lower quality then. Any investment could then possibly better pay off for the incumbent. If the entrant even pre-empted the incumbent in rolling out new infrastructure, the incumbent might also invest in order to keep up. Indeed, he could also try to seek access to the entrant's new infrastructure, but as the high access price also applies to him, this is rendered unlikely.

Implications if there were no business case

Ideally, such an access pricing policy aims to promote investment incentives by means of high access prices so that facility-based competition emerges. Given the presence of the incumbent's prevailing legacy network, a replication of the last mile infrastructure by entrants is strived for. Any roll-out of next-generation infrastructure by the incumbent does not fulfil this goal, although, technically speaking, it also refers to a replication. Yet, it is interesting to consider the effects of such an access pricing policy when the assumption of a business case no longer holds. For example, investment costs might increase with a decreasing density of population per area. Thus, at most one firm could be able to invest. Given the possible cost and information advantages of the incumbent, he might be more likely to invest then – if at all. Accordingly, when allowing for the absence of a business case in certain areas, two cases are of interest. Firstly, only the incumbent is able to roll out next-generation infrastructure in some areas. And secondly, none of the firms is able to invest in some areas.[13]

The first case implies that some areas will exist in which no replication of the last mile infrastructure has been undertaken by entrants but the incumbent, in contrast, has rolled out a new infrastructure of enhanced technology. In these areas, the above-cost access prices for the old as well as for the new network will then imply reduced static efficiency on both networks. Yet, the regulator might accept such a reduction (as long as it does not make the entrant quit) with respect to the aim of ensuring consumer welfare in the long run because at least one new network has emerged. In these areas, consumers now have the choice between an old-generation and a next-generation network. Consumers who are willing to switch will switch and benefit from an improved quality of service. But especially this choice would not be given when access regulation does not promote investment by above-cost access prices in the first place.

The second case implies that there will be areas in which the last mile infrastructure has been

[13] Of course, there is also the case in which the entrant is still able to roll out bypassing infrastructure in all areas. Yet, regardless of its employed technology, this implies the emergence of facility-based competition thereby fulfilling the policy goal.

neither replicated nor upgraded. These areas would then expose low static efficiency as the high access price for the old network inflates retail prices. As a remedy, the regulator could then apply regionally differentiated access prices for the old network as proposed by Bourreau et al. (2014) (while keeping an above-cost access price for the new network in order to maintain the incumbent's investment incentives). Areas where the regulator expects investment to be unfeasible could then rather have a cost-based access price for the old network in order to increase static efficiency (and to also prevent the entrant from quitting). In all other areas, a dynamically increasing above-cost access price for the old network would apply in order to still make the entrants invest. Yet, this requires good foresight by the regulator since he has to set these access prices ex-ante. The scenario's policy goal would be contradicted when naively ruling that as soon as new infrastructure has been rolled out, the old network will be subject to a cost-based access price in the respective areas. The entrant might then simply remain on the old network and no facility-based competition emerges. (See section 3.3.4.1)

Summing up, static efficiency is traded off for dynamic efficiency in this scenario. In the end, consumers benefit from infrastructure of enhanced quality and also from the emergence of facility-based competition. This is reached by enforcing investment by the entrant via a dynamically increasing above-cost access price for the old network and by disallowing to seek access to new infrastructure by mandating at least an above-cost access price for it. Such a joint regulation is necessary to give investment incentives to ensure the replication of the last mile infrastructure by entrants.

6 Accounting for a cable network: The Dutch case

The previous analysis and the deduction of implications for an optimal access pricing policy have been guided by empirical evidence and important theoretical literature. However, this theoretical work is restricted to the situation of one incumbent possessing the last mile infrastructure. Competing firms lack any infrastructure connecting to the premises of end-consumers. They accordingly rely on the incumbent or have to invest in bypassing infrastructure, thus becoming a facility-based competitor. Any existing facility-based firm, however, has been disregarded. That is, especially the presence of a competing cable network has not been accounted for.

Accordingly, the previous analysis cannot be directly transferred to the Netherlands, where a cable network covers large parts of the country. The Dutch broadband market with facility-based competition between the DSL and the cable network rather seems, to some extent, to be the final outcome of the previously treated theoretical studies. This section is, therefore, motivated to examine how competition from cable alters the previously derived implications. That is, to assess whether a Dutch regulator can also simply opt for promoting either static or dynamic efficiency. For this, the current situation in the Netherlands is briefly depicted. In addition, theoretical insights from models with two facility-based firms are presented that suit the Dutch situation. And finally, the implications for the optimal access pricing policies are elaborated on with respect to the previous scenarios.

6.1 The broadband market in the Netherlands

The Netherlands has the second highest broadband penetration per 100 households within all OECD countries (see Figure 1). Of the subscribers, 48 percent are on the DSL network and 45 percent on the cable network. The rest can be attributed to fiber lines. Among the different networks, there are significant quality differences. Figure 2 provides an overview. Obviously, a general uptake of speedier connections takes place, whereas the share of low-quality connections (i.e. download speeds below 30 Mbps) has dropped by 20 percentage points within two years. Though, especially the lower quality connections are provided by the DSL network, accounting for two thirds. In contrast, the cable network provides about two thirds of the higher speed connections (i.e. download speeds above 30 Mbps but below 100 Mbps), for which the DSL network has just recently started to catch up with the introduction of new technologies such as vectoring, pair bonding and phantoming. Yet, regarding very high speed connections (i.e. download speeds above 100 Mbps), the DSL network is not yet able to provide any connections without significant investments in new technology. The cable network, instead, can offer very high speed connections and accounts for two thirds, thereby just

having built up this share within the last few months. The fiber network, which is widely associated with very high transfer rates, only accounts for one third of very high speed connections. It has even lost market shares to the cable network in this regard (a drop from 43 percent of all above 100 Mbps connections in 2012Q4 to 34 percent in 2013Q3).

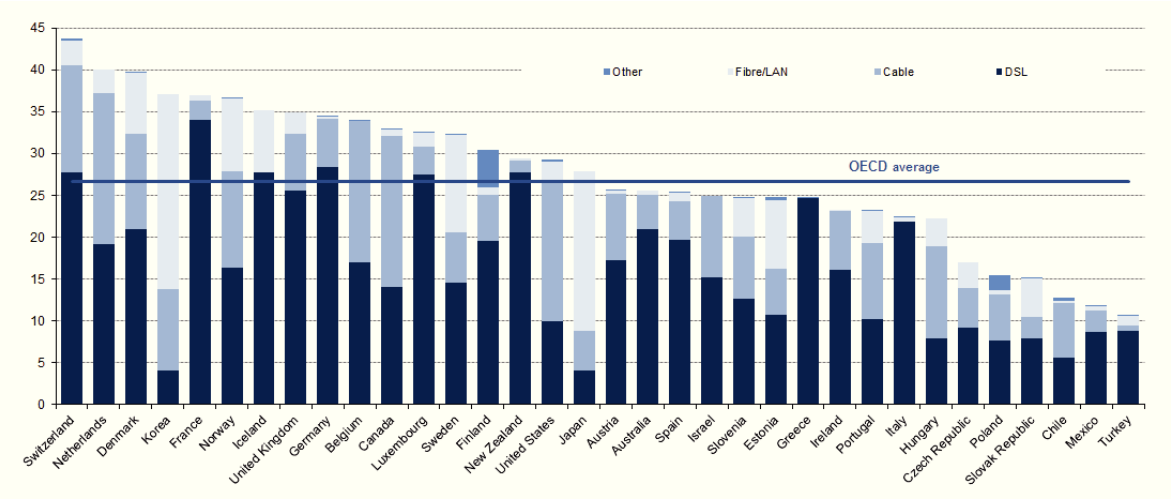
The current Dutch access regulation mandates operators with significant market power to provide access to their last mile infrastructure to competitors. Without going into technical details much, a somewhat above-cost access price cap is applied to the LLU access on the copper network. In fact, this access regulation only applies to the incumbent KPN. Via LLU access, entrants employ about 20 percent of the DSL lines.[14]

In addition to LLU, fiber unbundling is also mandated. Again, operators with a significant market power are obliged to grant access at an above-cost access price. Here, the regulator explicitly takes the incumbent's asymmetric risk into account (see section 3.1). Thus, entrants share part of the risk with the incumbent. The tariff ceiling is heightened with a so-called asymmetric regulatory increment. The access price for the fiber network is higher than the one for the copper network. Entrants, however, only employ a minor number of unbundled fiber lines. (OPTA, 2010)

In contrast, the cable network has until now not been subject to any broadband access regulation. Moreover, it is also observed that cable operators do not voluntarily grant access to their infrastructure to competitors. Neither do they seek access to alternative, unbundled last mile infrastructure (in areas where they do not possess an own infrastructure).

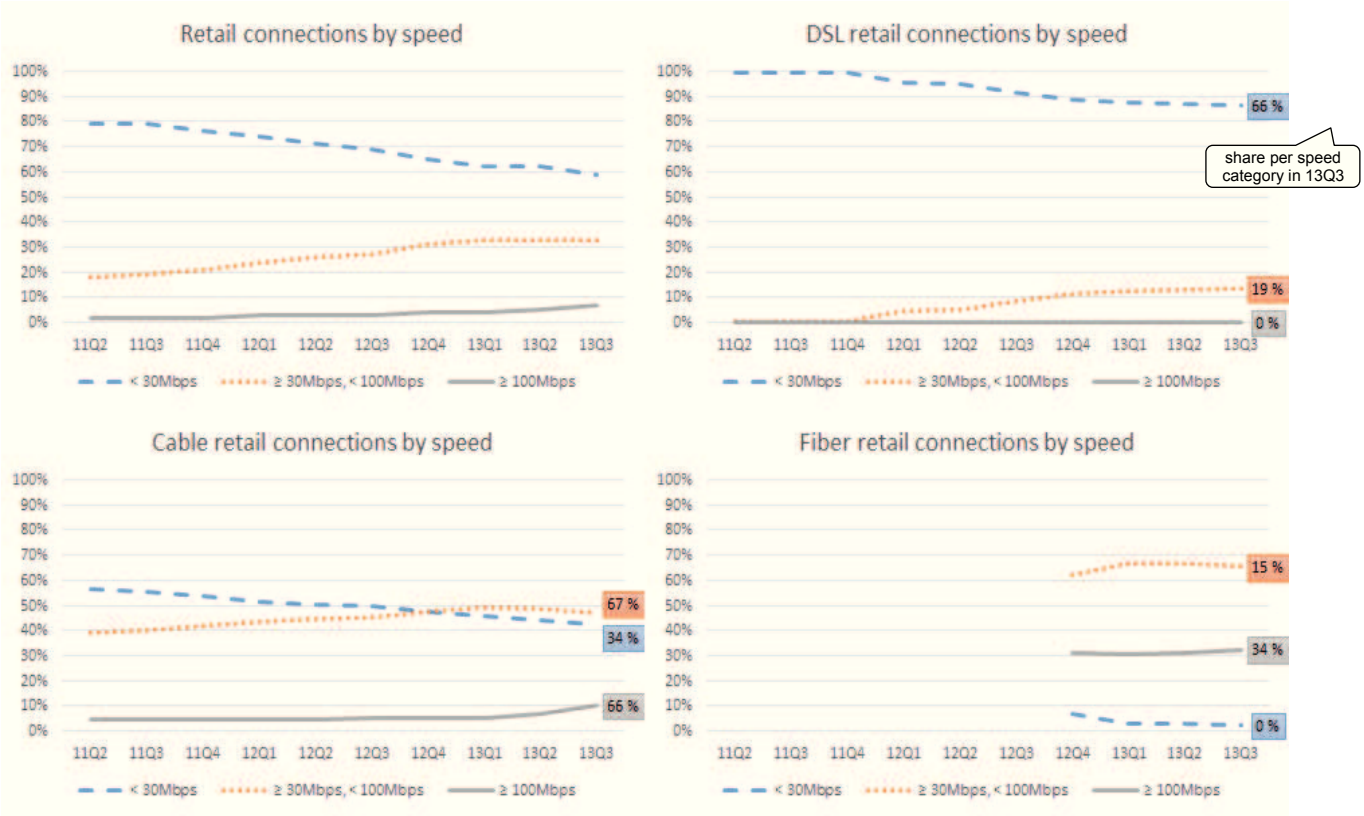
[14] Sources: Digital Agenda Scoreboard 2014 - Broadband markets, Broadband indicators, January 2014 (http://ec.europa.eu/digital-agenda/en/fast-and-ultra-fast-internet-access-analysis-and-data), ACM Telecom Monitor 2013Q4 (https://www.acm.nl/nl/publicaties/publicatie/12993/Telecommonitor-vierde-kwartaal-2013/)

Figure 1: Fixed broadband subscriptions per 100 inhabitants, by technology, June 2013



Source: OECD broadband statistics (http://www.oecd.org/sti/broadband/oecdbroadbandportal.htm)

Figure 2: Retail connections by speed and infrastructure (excluding wholesale supplies)



Source: ACM Telecom Monitor 2013Q3 - 2012Q4 and OPTA Structural Monitoring Markets 2012Q3 - 2011Q2 (https://www.acm.nl/en/publications/publication/12746/2013-Telecom-Monitor-Q3---increase-of-very-fast-broadband-connections/)

6.2 Theory on asymmetric regulation

In order to describe how the presence of an unregulated, facility-based competitor alters the implications of the previous scenarios, it is of interest whether theory exists suiting the existing Dutch situation. Especially the above-mentioned fact that cable operators in the Netherlands do not voluntarily provide access, helps to sort out the relevant theoretical literature.

Indeed, there exists some theoretical work that models two (or more) competing, vertically integrated firms and one entrant (e.g. Brito & Pereira, 2009, 2010; Ordover & Shaffer, 2007). Yet, it is assumed that the entrant can seek access to both firms' facilities. These studies then focus on

whether the firms would deliberately grant access to the entrant. The effect of access regulation is not their main point of interest. Yet, where touched upon, both facility-based firms are equally regulated. Therefore, this literature does not suit the Dutch situation in which the cable network is not subject to access regulation.

Alternatively, one could try to interpret the entrant as a cable operator that has its own network in parts of the country (i.e. it is a facility-based competitor to the incumbent) but seeks access to the incumbent's infrastructure in the rest of the country (i.e. it is a service-based competitor) as e.g. Bender and Götz (2011) do. However, this also does not correspond to the Dutch case as cable operators do not seek access to the DSL/fiber network.

Rather, relevant studies would have to deal with two facility-based firms, of which only one is mandated to provide access to an entrant and the other one does not deliberately grant access to it. To the author's knowledge, only two theoretical papers, which also consider investment, could be detected. On the one hand, Kocsis (2013) analyses such a setting of asymmetric regulation. She assumes that the cable operator initially has a higher quality of service and focuses on the incumbent's investment incentives to catch up. She finds that revenues from access charge payments to the incumbent compensate him for the uncompetitive, lower quality of his infrastructure and therefore hamper his investment. A higher access price might drive the entrant out of the market, which puts the incumbent into duopolistic competition with the cable operator. In order to become more competitive, the incumbent then engages in overinvestment.

On the other hand, Matsushima and Mizuno (2012) also consider a situation of asymmetric regulation thereby especially accounting for the cable operator's investment. An important assumption they make is that any investment by the incumbent also partly benefits the entrant. Therefore, with a regulated, cost-based access price the incumbent is less motivated to invest as this also helps the entrant without additionally benefiting himself. Though, Matsushima and Mizuno (2012) state that the presence of the additional facility-based firm leads to higher investment levels than if it were absent. Moreover, without access regulation, the incumbent would deliberately grant access to the entrant. As the investment also increases the number of the entrant's customers, the incumbent would use the entrant as his affiliate to attract consumers away from the competing cable operator. Though, thereby he would stipulate a high access price in order to absorb profits from the entrant. Still, investment levels are therefore higher than with access regulation.

Unfortunately, there exists no theoretical literature dealing with asymmetric regulation against the background of the transition from an old-generation to a next-generation network.

6.3 Evaluation of scenarios

In the following, the previous scenarios are evaluated regarding whether their suggested access pricing policies continue to meet the respective policy goals when a competing cable network is present (as in the Netherlands).

First scenario: Promoting service-based competition

The first scenario has described a situation in which a duplication of the last mile infrastructure is not deemed feasible and the regulator pursues high consumer welfare in the short run as policy goal (see section 5.1). The scenario has shown that service-based competition on the telephone network can be promoted by a cost-based access price in the absence of a cable network. This access price is not only applied to the old network but also to any possibly emerging next-generation network. Thus, consumer welfare can be enhanced via decreasing retail prices resulting from service-based competition.

The presence of another facility-based firm in form of a cable operator alters the impact of a cost-based access price on the firms. Regarding the old network, the cost-based access price still entails the emergence of service-based competition on it as entrants seek access. Accordingly, LLU leads to lower retail prices (as the empirical evidence shows while accounting for cable; see section 4.2). This implies that the cable operator also encounters more severe price competition regarding any services that are comparable to the quality of the old network. Therefore, it is likely that the cable operator tries to escape competition by innovation (i.e. the so-called escape effect in neck-and-neck competition (Aghion et al., 2005)). In fact, this is observable in the Netherlands: The share of cable connections in the above 30 Mbps speed range is steadily increasing whereas the respective DSL share remains low. Additionally, the cable network also provides more very high speed connections than the fiber network (see section 6.1).

Regarding the next-generation network, a cost-based access price for it (as advocated in the first scenario), however, limits the ability of the DSL firms to catch up with the cable operator, which independently invests in higher speeds being not subject to access regulation. For entrants, such access terms make access-seeking more profitable than investing themselves. Thus, entrants are less likely to roll out their own infrastructure. On the other hand, since the incumbent is mandated to provide access at terms that at most enable him to recover his investment costs but do not promise any further surplus, investment in next-generation infrastructure seems less likely. Of course, it is to acknowledge that the empirical evidence shows that competition from cable triggers more

investment in fiber lines (see section 4.1.1). Yet, as these studies are conducted on a cross-country basis, it is not clear whether the individual regulatory framework might have provided additional incentives. Still, the important point regarding this scenario is that the cost-based access price does not actively provide investment incentives – as intended since the focus is rather on the promotion of static efficiency in the telecommunications sector.

This has not been any problem in the absence of an unregulated, facility-based competitor. Static efficiency could always be promoted by mandating a cost-based access price for both the old-generation and next-generation network. Here, service-based competition is sufficient to ensure low retail prices and investment is not deemed necessary. Yet, with the presence of a competing cable network, investment is indispensable but cost-based access prices keep incentives to investment in next-generation infrastructure low (see section 5.1). As a result, the cable operator will lack competition regarding services of higher quality. The broadband market for higher quality services could then become monopolized by the cable operator (Hoernig, 2011; Kocsis, 2013). A suggestive trend is already observable in the Netherlands, where the cable network accounts for two thirds of the (very) high speed connections. Accordingly, in the long run, static efficiency in the telecommunications sector is endangered as consumers might then suffer from monopoly prices for higher quality services.

Therefore, it can be concluded that, with the presence of cable competition, the cost-based access pricing policy of this scenario might still be able to promote service-based competition on the telephone network and to accordingly keep consumer welfare high in the short run. However, in contrast to the situation without cable competition, this static efficiency cannot be maintained in the *whole* telecommunications sector in the long run as a monopoly could emerge.

An altered first scenario with an adjusted access pricing policy

Acknowledging the possible emergence of a cable monopoly, the regulator might change his initial preferences. Therefore, an altered first scenario is presented here. In contrast to the first scenario, the regulator does no longer aim to increase static efficiency via service-based competition. He rather wants static efficiency not to worsen in the long run while taking the current situation as given. That is, he acknowledges that facility-based competition between the cable network and the incumbent's network is already present. If however, the incumbent's network is technologically outdated, the regulator might want his regulatory policy not to hamper the incumbent's incentives to update it in order to retain a functioning facility-based competition in the future. In addition, the regulator desires to maintain the present service-based competition on the incumbent's prevailing

network assuming that there is no business case for the replication of the incumbent's last mile infrastructure by entrants.

How should the first scenario's access pricing policy be designed to suit the new situation? In order to come to the point, a conclusive answer cannot be given due to the shortfall of (theoretical) literature dealing with investment decisions in a setting with asymmetric regulation and next-generation networks. Though, some suggestions can be stated.

Undoubtedly, it is not conducive to alter the cost-based access price for the old network in order to stimulate more investment by the incumbent. Any higher access price clearly is at the expense of the welfare of consumers using the particular services of entrants as they would suffer from inflated retail prices if entrants pass on the higher costs. Thus, the policy goal of this scenario – not to hamper the current static efficiency on the incumbent's prevailing network – would be countered. Additionally, as Kocsis (2013) elaborates, high access-charge revenues from the old network might provide a compensation for the low quality infrastructure to the incumbent so that he might not be motivated to catch up with the cable operator. Hence, a higher access price even hampers investment by the incumbent. Accordingly, a cost-based access price for the old network is still appropriate in this scenario.

Regarding the access price for the next-generation network, a recommendation is less clear. Certainly, mandating a cost-based access price is not conducive either as outlined above. Entrants might then be more likely to seek access. The incumbent is indeed compensated for his investment costs but has no additional gain so that his investment effort might not be granted. Matsushima and Mizuno (2012) show that if his investment also enables the entrant to attract more consumers, the incumbent invests less since he does not want to support the entrant, which would otherwise increase the competitive pressure on himself. In contrast, an above-cost access price provides some surplus to the incumbent, thus making his investment more likely. If his investment also benefits the entrant, he would be more likely to invest as he now can also take advantage of the entrant's increased subscriptions via additional access-charge revenues (Matsushima & Mizuno, 2012).

It might also be possible to leave the next-generation network unregulated. The analysis by Matsushima and Mizuno (2012) suggests that, without regulation, the incumbent's investment level is highest as he then would freely set an access price in order to make use of the entrant's ability to attract consumers when using his new infrastructure. That is, the incumbent would utilize the entrant as his affiliate in order to compete with the cable operator. Thus, the absence of regulation might not lead to foreclosure.

Whether the regulator mandates an above-cost access price for the new network or leaves it

unregulated, it is essential to provide some investment incentive to the incumbent at all. Setting a cost-based access price for both networks cannot achieve this. This inability has rather been the starting point for this altered scenario since, in this way, investment in next-generation infrastructure by the incumbent is not warranted, and the cable operator might eventually monopolize the broadband market for higher quality.

Accordingly, with the presence of a facility-based competitor, static and dynamic efficiency intermingle with each other in this altered scenario. In order to retain static efficiency in the long run via a functioning facility-based competition, a deviation from promoting static efficiency in the short run has to be accepted. An above-cost access price for the new network (or, alternatively, leaving it unregulated)[15] seems to lower static efficiency on it. But in the long run, static efficiency might not be hampered due to two reasons. Firstly, the cost-based access price for the old network still promises sort of a base level of static efficiency. All customers could benefit from low retail prices for the old network. Secondly, consumers with a higher willingness-to-pay for enhanced quality could benefit from a wider range of quality being able to choose between two providers of high quality services. Such an access-pricing policy is, thus, also able to improve consumer welfare by preventing that consumer choice would be restricted to the cable operator's services of higher quality otherwise.

Second scenario: Promoting facility-based competition

The second scenario has initially started from the presumption that replication of the last mile infrastructure is feasible and the regulator pursues high consumer welfare in the long run as policy goal (see section 5.2). In this scenario, an optimal access pricing policy has been derived aiming for the emergence of facility-based competition. It suggests a dynamically increasing above-cost access price for the old network in order to incentivize entrants to invest in bypassing infrastructure. In addition, next-generation networks are also characterized by a high access price in order to impede entrants from seeking access to it. Thus, ultimately a state of facility-based competition can be reached, in which entrants are no longer reliant on the incumbent's choice of technology. Consumers would thus benefit from an increased choice of quality.

With the presence of a well-developed cable network in the Netherlands, however, there is already a situation of facility-based competition between the cable and the DSL network. Applying

[15] Since the analysis by Matsushima and Mizuno (2012) indicates that the incumbent's level of investment is highest without access regulation, one could prefer no regulation over an above-cost access price when aiming for investment. But basing a recommendation solely on their study is not adequate. More research has to be conducted with respect to the effect of the access price level on investment in a setting with asymmetric regulation and competing facility-based firms.

the access pricing policy of the second scenario then implies that the regulator actively strives for an additional infrastructure connecting to the premises of consumers. If this is what the regulator wants, and if he acknowledges that there is a business case for rolling out a further local network, then he can employ the second scenario's access pricing policy. That is, mandating a dynamically increasing above-cost access price for the old network and also a likewise high access price for the next-generation network (or even forbidding access to it with the help of a prohibitively high access price). Thus, the focus remains on the entrants' investment decision and such an access pricing policy ensures that they find seeking access (to both the old and the new network) less attractive and roll out their own infrastructure. In addition, the incumbent's investment incentives are not hampered as he even gets an above-cost compensation via both access prices. Moreover, as the access price for the next-generation network is also regulated, the incumbent is precluded from delaying investment by the entrant. Otherwise, it might be possible that the incumbent voluntarily grants access to his infrastructure at more beneficial access terms in order to have one potential facility-based competitor less (i.e. the replacement effect), thus running contrary to the policy aim of promoting investment by the entrant.

If it, however, turns out that there is no business case for a further network, such an access pricing policy might drive entrants out of the market. Kocsis (2013) shows that when entrants leave the market, the incumbent no longer receives access-charge revenues stemming from the above-cost access price for the old network. Thus, he is no longer compensated for the low quality of his old network and needs to strongly invest in order to keep up with the cable operator's quality.

The just described absence of a business case also corresponds to the case in which the regulator changes his policy goal and no longer strives for a replication deeming the existing facility-based competition from cable as sufficient. Still, in this scenario he might be interested in promoting dynamic efficiency, i.e. enhancing investment. Therefore, the access pricing policy of the second scenario can still be applied. The high access price for the old network might indeed drive the entrants out of the market. But in return, the incumbent is ultimately forced to invest in order to catch up with the cable operator. Hence, with such an access pricing policy, the regulator can provide a strong investment incentive to the incumbent.

However, this is clearly at the expense of entrants. The empirical evidence in fact shows that inter-platform competition leads to lower retail prices. But the shortfall of firms being active at the lower spectrum of quality hampers the welfare of the respective costumers. Thus, if the regulator does not aim for any further replication of infrastructure but nevertheless wants to stimulate more investment by the incumbent while simultaneously not losing too much static efficiency, he might

rather consider the access price policy of the above-mentioned, altered first scenario.

Conclusion

Abstracting from the presence of a cable network, the first scenario has initially been derived in order to promote service-based competition. It assumes that there is no business case for entrants to invest in bypassing infrastructure and accordingly suggests a cost-based access price for all networks. The presence of facility-based competition from an unregulated cable operator, however, challenges the neglect of investment incentives. While a cost-based access price for the next-generation network might hamper the incumbent's roll-out of next-generation infrastructure, the cable operator independently invests and could even monopolize the broadband market for higher quality, while the incumbent loses consumers to the cable network.

Therefore, an alternative scenario is conceived in which the regulator alters his access pricing policy in order not to hinder the incumbent's investment. Thus, the regulator would mandate an above-cost access price for the new network (or even let it unregulated). Yet, the regulator would then bear away from his initial aim to increase consumer welfare in the short run. In return, he would retain it in the longer run as he prevents a monopoly to emerge and also ensures that the existing facility-based competition in the broadband market for higher quality is conserved, in which consumers further benefit from an increased choice of quality (due to two providers instead of only the cable operator). Additionally, the regulator keeps a cost-based access price for the old network because any higher access price would lessen the incumbent's investment. Thus, the regulator could also maintain a base level of static efficiency serving especially the users of low quality.

Regarding the second scenario, which intends a replication of the incumbent's last mile infrastructure by the entrants, the presence of a cable network leads the regulator to reconsider his policy goal. Indeed, this implies that facility-based competition already exists. The regulator thus has to decide whether he wants the last mile infrastructure to be replicated once more. If so, he can apply the access pricing policy of the initial second scenario. A dynamically increasing above-cost access price for the old network and a likewise high access price for the new network ensure that entrants invest in bypassing infrastructure while finding access-seeking less attractive. In addition, the incumbent's investment incentives are also warranted. In the end, this implies that there will be (at least) three networks: the cable network, the fiber network of the incumbent and the fiber network of the entrant(s). If, in contrast, the regulator does not desire any additional last mile infrastructure or anticipates no business case for it, but still wants to promote investment by the incumbent, he might rather apply the access pricing policy of the altered first scenario.

However the regulator decides to regulate the DSL/fiber infrastructure, a question that he should also ask himself is whether to continue the policy of asymmetric access regulation, which regulates the DSL incumbent but not the cable operator. This subject becomes more important but is rarely dealt with in the literature. As an exception, Hoernig (2011) shows in a theoretical paper that such a policy provides a strong first-mover advantage to the cable operator, which could become a monopoly if it thus attracts away most consumers from the other network. According to Hoernig (2011), symmetric regulation could instead lead to higher consumer surplus by a reduction of local market power on the cable network. Consumers who are locked-in with the cable network (and are thus less likely to switch to the alternative network) would benefit from the creation of competition and a following reduction in retail prices.

7 Conclusion

This study examines the effects of access regulation on investment in the telecommunications sector from a static and a dynamic point of view. It reviews the relevant theoretical literature and also surveys empirical evidence. Additionally, it derives implications for optimal access pricing policies with and without the presence of a competing cable network. In the following, the main findings are summarized.

From a static point of view, access regulation aims to prevent that the incumbent forecloses entrants from access to his last mile infrastructure connecting to the premises of consumers. The incumbent might only deliberately grant access if entrants are able to provide better services, thereby attracting more consumers or increasing their willingness-to-pay. Yet, he would thereby stipulate an access price which is so high that he absorbs profits from the entrants. Access regulation can then promote service-based competition by mandating an access price equal to the marginal costs of providing access. This entails the entry of (more) cost-efficient firms, thereby driving down retail prices.

Theory on investment

With respect to the dynamic point of view, the theoretical literature regarding investment is comprehensive. Still, the reviewed studies have in common that they focus on an incumbent being mandated to provide access to entrants, but they disregard competition from another facility-based firm. They mainly differ in accounting for a prevailing incumbent's infrastructure. More recent studies also consider the transition from old-generation to next-generation infrastructure.

In the situation in which the incumbent possesses the last mile infrastructure and is not mandated to provide access to it, he might not solely foreclose the entrant, even if it is not able to attract further consumers. The reason is that technological progress might drive down investment costs so that investment in bypassing infrastructure eventually becomes profitable for entrants. Thus, the incumbent would ultimately face more severe facility-based competition. In order to impede this, he would deliberately grant access to his infrastructure at profitable terms. The so-called replacement effect then implies that entrants are less likely to invest since they would otherwise forego profits from seeking access. A higher, mandated access price could eliminate such opportunity costs ensuring that the entrants' investment incentives are not artificially kept low.

In contrast, if reputation matters for the entrant's ability to offer services over its own bypassing infrastructure, the incumbent might rather be incentivized to foreclose entrants. Thus, an entrant

could not build up a consumer base. If consumers do not trust a new entrant with its own infrastructure, its investment incentives might also be low. A sufficiently low access price might then be able to accommodate entry and the build-up of reputation. However, in the vein of the ladder of investment, the access price should dynamically increase in order to make access-seeking less attractive and to ensure that entrants finally take the last rung of the ladder and invest in bypassing infrastructure. In addition, an above-cost access price also provides some rents to the incumbent thus being more likely to invest.

In areas where no infrastructure is prevailing, the incumbent and the entrant are in principle equally likely to roll out new infrastructure. Yet, the incumbent might benefit from a funding or information advantage and moves first. In any case, an above-cost access price can accelerate investment by giving a pre-emption incentive. As it promises some surplus, firms would like to get into this profitable position and avoid any access payments. In contrast, a low access price could hamper investment as firms then find access-seeking more attractive and the potential first-mover would accordingly invest less. A carefully set access price can, thus, induce investment at the socially optimal date.

Furthermore, the roll-out of next-generation infrastructure is influenced by the access price for the old, prevailing infrastructure. If there is a low access price, cheap services from the old network might still be able to put competitive pressure on enhanced services using the new technology. Consumers might then be less willing to switch. This challenges the profitability of the next-generation infrastructure and investment might accordingly be hampered. A high access price, in contrast, mainly aiming for investment by entrants could also hamper the incumbent's investment. An entrant using its own infrastructure implies that the incumbent receives less access-charge revenues. In case that any investment by the incumbent makes consequent investments by entrants more likely, the incumbent might therefore invest less in the first place.

Moreover, access regulation on the next-generation infrastructure should consider that the access prices for both networks seem to be positively correlated. A high access price for the old network aiming to promote investment by entrants would be countered by a low access price for the new network. Entrants might then rather seek access to the next-generation network at such profitable access terms. The access price for the new network should then also be (prohibitively) high in order to impede this. Similarly, if there is a low access price for the old network, the migration of consumers from the old to the new network can only be triggered by a low access price for the new network. A high access price would otherwise make the new services more expensive, thus hindering migration because subscribers might then rather stick to the cheaper services of lower

quality.

Empirical evidence

The empirical studies suggest that the number of total broadband lines is only significantly increased by inter-platform (i.e. facility-based) competition. Intra-platform (i.e. service-based) competition seems to have no or only a temporary effect. Yet, when the situation of intra-platform is considered more in detail, a lower LLU access price can also trigger more total broadband penetration. In addition, regarding fiber penetration intra-platform competition has a negative effect on it, whereas inter-platform competition positively affects it. Though, it is noticed that competition from cable indeed can trigger more investment in fiber lines, but this does not ensure that consumers also switch to it.

Moreover, LLU leads to a reduction in retail prices and increases quality (i.e. download speeds). Competition from alternative technologies also tends to reduce retail prices. But the empirical evidence in this regard is not clear-cut, at least it can be stated that broadband services provided by alternative infrastructures do not seem to expose higher prices than DSL services. Additionally, it should be noted that the empirical evidence regarding the effect of access regulation on quality and prices is far less numerous than the one on investment.

Implications for optimal access pricing policies

Having thus answered the first research question, implications for optimal access pricing policies are derived from these insights, thereby addressing the second research question. For this, two scenarios with different policy goals are distinguished, which are motivated from a distinct interpretation of the empirical evidence: Since entrants seem to be stuck seeking access to the incumbent's last mile infrastructure, the failure of investment in bypassing infrastructure can either be attributed to non-feasibility or to an inadequate implementation of the ladder of investment approach. In this regard, the regulator might then decide whether to strive either for service-based or for facility-based competition depending on if he acknowledges a business case for the replication of the incumbent's last mile infrastructure by entrants.

Undoubtedly, a trade-off exists between static and dynamic efficiency. A regulator cannot actively promote investment without tolerating some cutback in consumer welfare, which results from an increased access price inflating retail prices. In return, however, consumers then benefit from the emergence of enhanced infrastructure, which provides a wider choice of services.

Accordingly, the first scenario, which prefers static efficiency and assumes no business case for

investment by entrants in bypassing infrastructure, indicates that a cost-based access price introduces service-based competition leading to lower retail prices. Yet, such an access price also hampers the incumbent's investment in new infrastructure especially because consumers are used to low retail prices and might be less willing to pay higher prices for increased quality thereby reducing the returns on such an investment. Nevertheless, alternative infrastructure might emerge for reasons independent of the access price. Access to it should then also be mandated at a cost-based access price in order to enhance consumer welfare via decreasing retail prices resulting from service-based competition.

In contrast, the second scenario, aiming for enhanced consumer welfare in the long run, concludes that the necessary investment for the emergence of facility-based competition is best triggered by a dynamically increasing above-cost access price. Such an access pricing policy ensures that entrants find access-seeking less and less attractive and eventually invest in bypassing infrastructure, for which a business case is assumed in this scenario. In addition, it is crucial that any next-generation infrastructure is also characterized by a high access price in order to impede entrants from seeking access to it. Only in this way, investment in bypassing infrastructure can be ensured. Moreover, an above-cost access price for both networks also warrants the incumbent's investment, whose returns in this case might not be hampered by retail prices for the old network that could undermine the willingness of consumers to switch.

Taking cable competition into account

The previous theoretical analysis and the deduction of implications for optimal access pricing policies abstract from any presence of a competing, unregulated cable network. This is attributed to the lack of theoretical literature accounting for additional facility-based competitors. However, this implies that the derived access pricing policies cannot be directly transferred to the Netherlands, where a cable network accounts for almost half of the total broadband penetration. So to speak, the Dutch broadband market represents to some extent what most theoretical studies aim for: facility-based competition. Therefore, besides presenting the scarce, related theory, this study also assesses whether the derived access pricing policies fulfil their goals in case competition from cable is present. Thus, the third research question is addressed.

The access pricing policy of the first scenario fails as the incumbent's investment is hampered and the cable operator might monopolize the broadband market for higher quality services. Accordingly, an adjusted access pricing policy is suggested: a cost based-access price for the old network and an above-cost access price for next-generation infrastructure. Thus, the incumbent's

investment can be ensured in order to maintain future facility-based competition for higher quality services. In contrast, the access pricing policy of the second scenario can continue to trigger investment by entrants. Yet, while already facing facility-based competition between the DSL and cable network, the regulator has to decide whether he desires any further replication of the last mile infrastructure.

Scope for further research

The review of the theoretical and empirical studies has also shown that there are still some blank spots that deserve further research. Highly relevant is further investigation regarding the effects of access regulation on investment with the presence of another facility-based firm which is not regulated. Especially, the incumbent's decision to roll out next-generation infrastructure should thus be accounted for. Relatedly, more research on the impact of switching towards a symmetric regulatory regime is of interest. Here, another important question is whether the DSL/fiber and cable network should be equally regulated or whether both should be left unregulated.

Even though in recent years, more empirical studies have been conducted with respect to the effects on fiber deployment and retail prices, more research especially regarding the effect of access regulation on quality is advisable. In order to better understand the impacts of different designs of access pricing policies, more country-specific case studies might also be helpful.

Autoriteit
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Appendix: Detailed descriptions of theoretical models

This appendix provides a more detailed description of the models dealt with in the main text. It thereby also follows its structure.

A.1 Effects on the incumbent's investment in his prevailing infrastructure

A.2 De Bijl and Peitz (2007)

De Bijl and Peitz (2007) model a strategic interaction between a vertically integrated incumbent and a non-integrated entrant seeking access to the incumbent's local loop. These firms offer services that the consumers perceive as imperfect substitutes (e.g. due to switching costs). Hence, there is a situation of imperfect service-based competition in which the presence of an entrant already can act disciplining on the incumbent. Introducing a regulator which sets an invariant access price ex-ante (i.e. before the investment is conducted), De Bijl and Peitz (2007) describe the effects on the incumbent's investment in quality, which has the ability to expand the demand for his product (which thus increases its price). Thereby they distinguish between the situations of full and partial consumer participation. Partial consumer participation depicts a non-mature market in which demand depends on prices, i.e. new consumers will enter the market with decreasing retail prices and/or better quality of products. In contrast, demand is perfectly price-inelastic with full consumer participation, i.e. all possible consumers are already in the market and will always buy the product regardless of its price.

In the case of full consumer participation, a higher access price will therefore be fully passed on to the consumers. Moreover, a higher access price will increase the incumbent's profit as he will receive more access charge payments from the entrant. As investments in quality can expand demand, the incumbent has always an incentive to conduct such investments in order to further increase his profit flow. De Bijl and Peitz (2007) point out that this incentive is always given and, thus, is unrelated to the access price. Hence, there are two sources of profits to the incumbent: access charges and the increased demand due to investments in quality. Thus, in order not to grant unduly profits by means of the access price, they suggest to link the access price to the level of the quality of infrastructure. It is further noted that as the entrant's profit is neutral to the access price (as it is fully passed on to the consumers) the incumbent's investment incentive is independent of the degree of competition in the mature market.

The other case regards partial consumer participation. Here, the entrant is able to expand the market by offering specific services which the incumbent cannot offer. In this setting, the incumbent would get a new incentive: It would be in his interest not to set the access price too high in order not to decrease his access charge revenues. The reason is that, in this setting, an increase in the access price leads, as before, to higher retail prices charged by the entrant. Yet, since there is partial consumer participation, increased retail prices will reduce the demand for the entrant's services and thus lower the incumbent's access charge revenues. Due to this elastic demand for the entrant's specific services and as the entrant may even charge a mark-up due to possible market power, it would be optimal for a welfare-maximizing regulator to set an access price below the value that he would set in a perfectly competitive setting. Such a lowered access price would enable the entrant to serve its customers at a lower cost. Accordingly, this would also encourage entry. Regarding the incumbent's incentive to invest, an access price depending on quality is, again, able to induce investment in the partial consumer participation setting.

A.2.1 Vareda (2007)

Vareda (2007) also models a strategic interaction between a vertically integrated incumbent and a non-integrated entrant seeking access to the incumbent's local loop. Both firms offer differentiated services, but the quality of infrastructure is equal for both, hence there is imperfect service-based competition. Employing a partial consumer participation setting, he studies the effects of access regulation on the incumbent's incentives to invest in quality and in cost-reductions. He also analyses the effects of the regulator's commitment to ex-ante set access prices.

In absence of regulation the incumbent has always an incentive to unbundle its infrastructure since the entrant attracts more consumers and the incumbent can set a higher (than socially optimal) access price in order to absorb profits. The incumbent's incentives to invest are nevertheless low. Investing in cost reduction would only profit the incumbent and give him a cost advantage which, in the end, would attract consumers away from the entrant. In this setting, this is not of interest for the incumbent as he would forego access charge profits. However, investing in quality could be an option for the incumbent as long as this also leads to an increase in the entrant's subscribers and, thus, in the incumbent's profits from access charges.

In the case of regulation, in which the regulator is able to commit to an invariant access price before the investment is made, changing the access price would have the following effects. Lowering the access price intensifies competition (via more entry) and would incentivize the incumbent to invest in cost reduction in order to gain a cost advantage. Quality upgrades would instead benefit both firms and are, therefore, unlikely but still possible due to a complementary relationship between both forms of investment: Higher quality augments the marginal benefit of investing in cost reduction as it lowers the cost of serving more consumers. Thus, if the incumbent is not attracting too many consumers away from the entrant due to his cost reduction investments, he may still engage in quality upgrades to expand the entrant's consumer base, which, again, gives him higher access charge revenues. Inversely, a higher access price would not trigger investments in cost-reduction for the aforementioned reason of attracting away consumers, but quality upgrades would be more likely if they can increase the number of the entrant's subscribers. Optimally, the regulator sets a higher (lower) access price when the investment in quality upgrades (cost reduction) is less expensive in order to induce such investments.

In the case in which the regulator is not able to commit to an access price ex-ante the incumbent anticipates that after his investment is made the regulator will set such an access price that he will always earn zero profits. Accordingly, the incumbent will not decide to invest at all. In this sense, a setting without regulation could yield more social welfare.

Finally, Vareda (2007) also examines the case of full consumer participation. Here, quality upgrades cannot attract any further consumers and are only conducted if they lead to an increased willingness-to-pay of consumers. This allows for increased retail prices which also will increase profits. Furthermore, the incumbent will always invest in cost reduction due to gaining a cost advantage. The regulator would, therefore, employ the access price to induce quality upgrades. The access price should then be sufficiently high.

A.2.2 Foros (2004)

Foros (2004) also examines service-based competition only and models a strategic interaction between a vertically integrated incumbent and a non-integrated entrant seeking access to the incumbent's local loop. There is also partial consumer participation and both firms differ in their ability to offer services at the retail level. Thus, they differently benefit from an incumbent's investment in the quality of infrastructure. (Yet, before the investment their services are substitutes). Foros (2004) provides different cases depending on which firm benefits more and on whether there is regulation.

In the absence of regulation and if the incumbent does not invest, he will foreclose the entrant by setting a prohibitively high access price in order to serve the market as a monopolist. If he invests and has a higher ability to offer value-added services and thus to expand the market, he will also foreclose the entrant. The incumbent will only grant access to the entrant after his investment if the entrant has a higher ability, but then the incumbent will set a high access price in order to absorb the entrant's profits.

When regulating access the regulator is assumed to set an access price ex-post (i.e. after the investment is conducted) equal to marginal costs. If both firms do not differ much in their ability to offer value-added services, such an access price would reduce the incumbent's investment incentive since he would neither be able to gain any profits nor to recover his costs but the entrant would instead benefit. The same is true if the entrant has an even higher ability and would benefit more from an investment in quality. An access price equal to marginal cost might only enable the regulator to impede that the incumbent uses the access price as a tool of foreclosure when the incumbent itself has the highest ability. However, Foros (2004) points out that the incumbent then might employ a non-price form of foreclosure: If the incumbent has a higher ability to offer value-added services (i.e. after an investment he can provide better services than the entrant), he could drive the entrant out of the market by overinvesting and supplying the whole market alone. This results from the assumption of Cournot competition, i.e. firms compete over quantities (e.g. subscriptions) rather than over prices (which is assumed in most other papers).

A.2.3 Kotakorpi (2006)

Kotakorpi (2006) employs in fact a similar setting of service-based competition like Foros (2004). Yet, a significant difference is that she assumes a competitive fringe to seek access to the vertically integrated incumbent's local loop. That is a group of small, price-taking firms which provide identical services and set their retail prices equal to their marginal costs. There is also partial consumer participation. The incumbent's investment in quality is able to expand the demand for his service and will also profit the rivals by increasing the demand for their services.

In the absence of regulation, such (sufficiently high) positive spillovers from an investment will induce the incumbent to invest and to grant access in order to benefit from the increased demand for the entrants' services. For this, however, he will set high access prices in order to absorb their profits. On the other hand, if these spillovers are low and, thus, the demand for the entrants' services does not rise and the incumbent's profits do not expand, he has little incentives to invest.

In the case of regulation, in which the regulator sets the access price ex-post equal to marginal costs, these spillovers negatively affect the incumbent's incentive to invest as he would not be able to make any profits (and recover his costs) but the rivals would instead benefit. If the rivals profit more from an investment than the incumbent, he would not decide to invest. With low or no investment, entrants may also find it unattractive to enter the market at all as the quality of the network might not be sufficiently high in order for them to provide their services. In this sense, underinvestment would lead to foreclosure (in contrast to overinvestment as in Foros (2004)). This is especially harmful to consumer welfare in the case of high spillovers, in which the rivals' services would contribute to expanding the market (and thus to serving more consumers).

A.3 Effects on the entrant's investment in bypassing infrastructure

A.3.1 Bourreau and Doğan (2005)

Bourreau and Doğan (2005) examine the incentives of an entrant to develop an alternative infrastructure. In contrast to the aforementioned papers, this implies the introduction of facility-based competition in addition to the service-based one. They model a strategic interaction between a vertically integrated incumbent and a non-integrated entrant which seeks access to the incumbent's local loop and/or invests to bypass it. As adoption costs are assumed to decline over time (due to technological progress), the entrant will always invest; Bourreau and Doğan (2005) hence study when it will invest. Service-based and facility-based competition are therefore no necessary complements. Their setting further comprises full consumer participation and a quality-increasing

character of the entrant's investment. Moreover, the incumbent is assumed not to invest.

In the absence of regulation and of technological progress, the incumbent would foreclose the entrant by demanding a prohibitively high access price and would benefit from a monopoly position. However, the introduction of declining adoption costs alters this behaviour. The incumbent now takes into account that the entrant will eventually bypass. The entrant's decision to invest in its own bypassing infrastructure stems from a discounting consideration of costs and benefits. In contrast to the case in which the incumbent forecloses the entrant, the incumbent now has an incentive to grant access to the entrant thereby introducing additional opportunity costs of investing to this consideration. If the incumbent allows the entrant to get some profits when leasing the local loop, this adds to the cost side of investment (in the form of foregoing these profits when deciding to invest) and therefore delays the occurrence of facility-based competition. This is clearly intended by the incumbent as this expands the period in which he can benefit from further access charge profits. The incumbent will therefore set a lower access price which allows the entrant to gain some profits. This mechanism is also known as the replacement effect: The replication of infrastructure by the entrant can be hastened by higher access prices or accordingly delayed by means of more favorably access prices.

A regulator takes into account that the entrant would, in this manner, invest too late from a welfare point of view and therefore mandates access at higher (invariant) access prices in order to accelerate facility-based competition.

Extensions of their model

Bourreau and Doğan (2005) further discuss how this thought changes when the entrant can chose between investments of higher or lower quality (whereby both are higher than the incumbent's quality). One can imagine the case of fiber optic cables and a cheaper technology of lower quality. If the entrant initially plans to adopt the lower quality technology, the regulator can still accelerate this by a higher access price, which lowers the opportunity costs for the entrant. However, if the entrant plans to adopt the higher quality technology, lowering the opportunity costs by increasing the access price might not suffice. The regulator might then even rule out access seeking in order not to delay this adoption, he thus eliminates any additional opportunity costs.

In an extension, Bourreau and Doğan (2005) also examine the case in which the incumbent is able to improve his infrastructure up to the same quality which the entrant could achieve by means of investment. Yet, the incumbent is assumed to invest before the entrant. This gives the incumbent an even stronger incentive to deliberately grant access in order to recover his costs and to absorb profits

from the entrant. The entrant's decision to enter facility-based competition is even further delayed as his expected profits from doing so are reduced due to a smaller quality advantage of its potential infrastructure compared to the incumbent's newly improved infrastructure.

Moreover, in a further extension Bourreau and Doğan (2005) also suggest the introduction of a time-variant access price in order to increase social welfare in the period before the entrant adopts the new technology. (Recall that in this period the incumbent faces no competition and thus acts like monopolist thereby diminishing consumer welfare.) By setting ex-ante a lower than the unregulated access price in this period, the regulator would be able to induce service-based competition. At the moment when the entrant's adoption of the new technology becomes socially optimal, the regulator would then increase[16] the access price above the unregulated access price, thus enforcing the adoption by lowering the opportunity costs sufficiently.

A.3.2 Bourreau and Doğan (2006)

The last-mentioned idea is further developed in an analogous setting in Bourreau and Doğan (2006). They highlight that in absence of regulation, the incumbent would set an access price path which decreases over time in order to offset the steadily decreasing adoption costs of new infrastructure resulting from technological progress. These decreasing costs make the adoption of new technology more attractive for the entrant. The incumbent, however, wants to delay this adoption and thus introduces opportunity costs of investing by granting access to the entrant at profitable terms. Thereby he takes into account that a decreasing access price over time will delay the entrant's investment even longer than a time-invariant access price could do. Regarding the regulator's optimal access pricing, Bourreau and Doğan (2006) even ratchet up their earlier suggestion by proposing that at the social optimal adoption date access seeking should be banned (or equivalently a prohibitively high access price should be set) in order to induce the entrant to roll out its own infrastructure at this date.

A.3.3 Avenali et al. (2010)

Avenali et al. (2010) also examine the incentives of an entrant to invest in a bypassing infrastructure. They model a strategic interaction between a vertically integrated incumbent and a non-integrated entrant which seeks access to the incumbent's local loop and may subsequently invest to bypass it. Hence, service-based and facility-based competition are assumed to be complementary, which is

[16] The regulator does not increase the access price ad hoc but rather has ex-ante committed to do so at the pre-set date.

due to a reputation effect. The entrant may indeed be able to provide services of enhanced quality, but as long as competing on the service-based level its service will be perceived as of lower quality by the consumers. Then, once the entrant becomes active on the facility-based level, its quality will be perceived as higher (also higher than the incumbent's quality). This setting thus attributes a first-mover advantage to the incumbent, which the entrant only can overcome by building up an own consumer base that strengthens its reputation. Their model also comprises partial consumer participation in the sense that on the facility-based level both firms compete for newly attractable consumers.

In the absence of regulation, the incumbent will clearly foreclose the entrant (by demanding a prohibitively high access price) in order not to allow it to build up reputation and hence to avoid the occurrence of facility-based competition (as later direct entry into the facility-based level would not benefit the entrant since its services would be perceived as of low quality).

Regulation could therefore impede this foreclosure and further induce efficient investment by setting ex-ante a time-variant access price which rises over time. To promote service-based competition in the beginning, the regulator sets the access price equal to marginal costs. The incumbent thus gets no profit and the entrant can build up a consumer base. Later the access price would rise, which makes further access seeking less attractive, in order to induce the entrant to invest and to enter into facility-based competition.

However, Avenali et al. (2010) point out that this regulation crucially depends on the credibility of the regulators ex-ante commitment not to change this access price path. For this, they provide a case in point in which the regulator might support the late entry of another entrant by setting the current access price again equal to marginal costs (in order to enlarge the market for further consumers that are attracted by the late entrant). This, however, disincentivizes the former entrant to invest. The regulator thus faces a trade-off between incentivizing the former entrant to invest and to allow the late entrant to enter (it might not enter facing a higher access price). The prevailing access price cannot simultaneously fulfill both goals. Therefore, Avenali et al. (2010) suggest that the regulator sets ex-ante an access price schedule, which depends not only on time but also on the date of entry, in order to charge every entrant timely differently but based on an equal schedule (i.e., in the language of the ladder of investment, offering each entrant an exclusive ladder which exposes the same conditions to each entrant independent of its date of entry; this also implies that there are multiple levels of entry).

A.4 Effects on the investment in new infrastructure without prevailing infrastructure

A.4.1 The decision when to roll out new infrastructure

A.4.1.1 Hori and Mizuno (2006)

Hori and Mizuno (2006) examine an investment race between two firms to roll out new infrastructure. Both firms employ the same production technology so that no firm has an advantage when entering the new market. Their setting includes uncertainty in the form of stochastically growing demand, i.e. firms know that the demand for their services will increase over time but in the short-term it is unsure by how much. On the one hand, this implies that firms might delay their investment decision as their short-term profits are uncertain. On the other hand, the growing demand also ensures that investment will eventually occur when demand will be high enough promising to break even. Yet, a socially non-optimal delay seems obvious as firms are assumed to only base their investment decision on the currently observed demand.

An ex-ante set (time-invariant) access price can then accelerate the leader's investment by generating a preemption incentive: The first-mover will get access charges from the second-mover (as long as the latter seeks access). A higher access promising some profits to the leader encourages investment. A sufficiently high access price can imply investment at the socially optimal date. In contrast, a higher access price to be paid by the follower reduces its time span of access seeking. This is due to the replacement effect, i.e. the accordingly decreased opportunity costs of investing (due to lower profits while seeking access) accelerate the follower's investment.

Hori and Mizuno (2006) focus on the case of an access-to-bypass equilibrium, which means that the leader invests and the follower sequentially seeks access but ultimately also invests in its own infrastructure. They show that the conditions for this equilibrium to arise are, on the one hand, that the leader has to get a higher profit under service-based than under facility-based competition in order to invest. On the other hand, investment costs have to be sufficiently high and/or the access price has to be sufficiently low to induce the entrant to first seek access. It these conditions are met, the access-to-bypass equilibrium exists. Otherwise, it might also be possible that both firms simultaneously invest in their own infrastructure.

A.4.1.2 Hori and Mizuno (2009)

In a later study with the same setting, Hori and Mizuno (2009) confirm that in the afore-mentioned access-to-bypass equilibrium (see section A.3.1.1) the follower enters the market earlier and builds a bypassing infrastructure later than in the situation with no mandatory access. Again, this is due to the

replacement effect. Moreover, with increased uncertainty the follower's investment is further delayed.

Regarding the timing of investment by the leader, Hori and Mizuno (2009) show that in the situation with no mandatory access the leader invests earlier when he expects higher monopoly rents in the period until the follower builds its bypassing infrastructure. In contrast, the leader might invest earlier in the access-to-bypass equilibrium than in the situation with no mandatory access when the expected monopoly rent as well as uncertainty are small.

Finally, Hori and Mizuno (2009) extend their model by assuming that the two firms now have heterogeneous production technologies. They state that in this case the firm with the more advanced technology (or generally lower costs) always enters the market as the leader.

A.4.1.3 Vareda and Hoernig (2010)

Vareda and Hoernig (2010) also examine an investment race between two firms to roll out a new infrastructure. They also model two symmetric firms employing the same production technology so that no firm has an advantage when entering the new market. Yet, after entering the leader will gain a first-mover advantage in the form of higher payoffs that result from the benefit of a higher customer base which is more loyal to the leader. In addition, they do not deal with uncertainty but assume the investment costs to decline due to technological progress. In contrast to Hori and Mizuno (2006), this (instead of a stochastically growing demand) will ensure that the follower eventually invests. It is to mention that in this investment rivalry setting both firms race to invest first. Yet, a simultaneous investment by both firms is ruled out so that there will always be an investing leader and an access-seeking follower, which still will eventually invest.

Vareda and Hoernig (2010) identify several incentives to invest. Firstly, there is a stand-alone incentive that results only from the increase in (retail) profits after investment. Secondly, there is a preemption incentive stemming from both the access charge revenues the leader receives from the access seeker and the eventually higher payoffs from the higher customer base. Thirdly, the follower might invest not only in order to avoid the profit-reducing access payments but also in order to be able to better differentiate its services from the leader. Finally, in contrast, there also exists the incentive to wait until technological progress has sufficiently reduced the costs of investment.

The influence of the access price

An ex-ante set access price affects these incentives. A low access price results in a predominance of the waiting incentive which is due to two reasons. On the one hand, preemption would not pay off since the access revenues would not promise sufficient profits (to recover at least the costs of

investment). On the other hand, both firms would prefer to seek access on such low access fees. Accordingly, both firms will not invest until technological progress has sufficiently reduced the costs investment.

On the contrary, a high access price strengthens the preemption incentive in the sense that both firms are eager to invest early in order to obtain the profitable access charge revenues. Yet, a high access price might also delay the first investment by the leader. This results from the thought that a higher access price makes being the follower less attractive as the follower has to pay higher access fees and therefore encounters reduced profits. This is the replacement effect arising from decreased opportunity costs of investment. Thus, the follower might invest earlier. This, in turn, reduces the period in which the leader receives access charge revenues from the follower. With an accordingly reduced return on his investment, the leader might thus delay his investment.

Vareda and Hoernig (2010) state that a time-invariant access price cannot achieve a socially optimal investment by both leader and follower. They suggest two modes of regulatory intervention. First, they propose to ban access after a pre-set date. A sufficiently high set access price will ensure that the leader invests at his socially optimal date. But in order to induce the follower not to delay its investment but to invest at its socially optimal date, the access price has to be set prohibitively high from that date on. This will eliminate the follower's opportunity costs of investment accordingly so that it immediately invests.

Another means is the so-called access holiday, which is a remedy to the occasion in which the follower might even invest too early than at its socially optimal date if its preemption motive is reinforced by a business stealing incentive, i.e. it heavily aims at capturing the leader's customers. Obviously, the regulator could set a lower access price to accordingly delay the follower's investment. Yet, this adversely affects the leader's investment incentive so that he might invest too late. A fixed time period after the leader's investment during which the leader is not subject to mandatory access then preserves the leader's investment incentives. In this time period the leader could deliberately grant access to the follower, but he would not since he rather could enjoy monopoly rents until the follower's eventual investment. This clearly is at the expense of (static) consumer welfare. Vareda and Hoernig (2010) admit that this loss cannot be fully eliminated. The necessary length of the access holiday and the necessity to avoid early bypass have to be traded off. Due to the follower's business stealing incentive it might already invest during the access holiday.

In order to delay its investment, access should be mandated just at this date. The access price then has to be set sufficiently low so that, on the one hand, the follower would then enter service-based competition (which reduces the loss of consumer welfare) and, on the other hand, the leader's

investment incentive is sufficiently protected.

Extensions of their model

In an extension, Vareda and Hoernig (2010) deal with the case in which the follower's investment in bypassing infrastructure is not desired. The regulator then has to set such an access price which, on the one hand, guarantees the profits which make the leader invest at the optimal date, but, on the other hand, is sufficiently low to ensure that the follower always seeks access. This can also be achieved by a sufficiently long access holiday followed by an accordingly low access price.

Moreover, they also study the case of two asymmetric firms, i.e. one firm has a lower cost of investing. The higher the cost difference, the later will the firm with higher costs invest. Thus, it will always be the follower whereas the firm with lower costs will always be the leader. Hence, there will be no situation in which both firms wait until technological progress has sufficiently reduced the investment costs. The regulator might then only be concerned about the dates of investment. Here, he can employ the banning of access or access holidays as described above.

A.4.2 The decision where to roll out new infrastructure

A.4.2.1 Lestage and Flacher (2010)

Lestage and Flacher (2010) study how access regulation affects the decision where to roll out new infrastructure. In their setting two ex-ante asymmetric firms, an incumbent (which can provide better service) and an entrant, simultaneously decide whether or not to invest in each area of a country. Moreover, they assume that the investment costs increase with a lower density of population.

Thus, in a situation without access regulation, the firms' decisions to invest depend on the investment costs and on the service quality advantage of the incumbent. In areas with a low population density none of the firms will invest. In contrast, in areas with high population density both firms will invest in their own infrastructure. In the remaining areas, the incumbent will invest as the exclusive firm if his advantage is significant. In this case, he will foreclose the entrant as granting access to it only lowers his retail profits. Yet, if the incumbent's advantage is not significant, both firms are equally likely to invest as the exclusive firm in those areas. In the case in which the entrant has invested as the only firm, it will, however, grant access to the incumbent as his better service quality can attract consumers. Thus, the entrant can compensate its loss in retail profits by increased access charge revenues.

Mandating access at an ex-ante set access price, which applies equally for both firms and uniformly in each area, affects the firms' investment incentives. A lower access price reduces the

investment incentives as firms find it more attractive to seek access. In addition, when providing access they also face reduced retail profits which cannot be offset by access charge revenues as these are capped by the lower access price. Hence, mandated access at marginal costs may impede the foreclosure in those areas where the incumbent has a monopolistic infrastructure. Yet, Lestage and Flacher (2010) show that mandated access also decreases investment. On the one hand, it enlarges the area where none of the firms invests. On the other hand, it shrinks the area where the high density of population would otherwise have led to the roll-out of two networks.

A.4.2.2 Bourreau et al. (2012)

Bourreau et al. (2012) also study the geographical aspect of rolling out new infrastructure. Specifically, they examine the impacts of setting ex-ante different access prices in different areas. In their setting two symmetric firms simultaneously decide where to invest, i.e. both firms face the same investment costs which differ per area. Thus, their analysis is independent of existing infrastructure.

In general, the decision to invest depends on the net benefits obtainable in each area. On the one hand, investment will decrease with higher investment costs in the respective areas. On the other hand, however, their setting allows firms to set different retail prices per area. Thus, firms can partly respond to different investment costs.

Accordingly, in a scenario in which no access to the new infrastructure is allowed, three differently covered areas will emerge: One with two networks as both firms have invested, one with one network as in the respective areas investment costs are so high that only one firm can profitably enter, and finally one where none of the firms has invested due to too high investment costs.

For their next scenario, Bourreau et al. (2012) introduce a third firm, a late entrant which does not invest but seeks access to the new infrastructure. This implies that in those areas where both former firms have rolled out their own infrastructure one firm will provide access to the late entrant. Hence, this firm might, depending on the level of access price, encounter higher or lower profits than the other firm. Yet, also the other firms might decide to seek access. Especially in areas with only one infrastructure access will then be provided to two firms.

In order to analyse the impact of mandated access on investment, Bourreau et al. (2012) distinguish three regimes. Though, in general they find that a higher access price encourages investment by both firms as providing access to the late entrant then yields higher access charge revenues.[17] Their first regime comprises the setting of access prices according to the marginal costs

[17] Of course, only one firm will provide access to the entrant, but when deciding whether to invest each firm calculates with the probability that the entrant will seek access on its very own infrastructure. As long as this probability and the

in each area. They state that this will reduce investment by making the return on investment less profitable. Hence, there will only be a low coverage of new networks. Moreover, there will not be any area with two new networks as the other firm will find it more attractive to seek access than to invest itself.

In the second regime a uniform access price is applied to all areas, thus disregarding any variation in investment costs. Setting the access price above marginal costs will result in more investment by both firms. Thus, areas with two networks will emerge. The number of areas with only one network will also increase. Yet, the increased access price goes along with higher retail prices and thus reduces static efficiency. Still, in terms of social welfare this regime is better than the previous one.

Their last regime comprises access regulation in areas with only one infrastructure and light access regulation in areas with two infrastructures, i.e. providing access to the entrant is obliged there but the access price is negotiated on a commercial basis. Bourreau et al. (2012) show that this could increase the number of areas with two networks as the investing firms expect to provide access to the late entrant at a profit-promising access price. By rising the access price, which only applies to areas with one infrastructure, the regulator can even increase the total coverage of new infrastructure compared to the unregulated case.

A.5 Effects on the investment in new infrastructure with prevailing infrastructure

A.5.1 Bourreau et al. (2011)

Bourreau et al. (2011) study the migration from a legacy network to a next generation network. They model a strategic interaction between a vertically integrated incumbent owning the legacy network and an entrant which accesses the legacy network. In their setting, investment costs differ per area. For each area, both firms sequentially decide whether to invest in a next generation network. The incumbent is assumed to invest first due to a first-mover advantage which results from his ownership of the legacy network (and e.g. related information advantages). In addition, the incumbent also has lower investment costs but his investment is assumed to generate positive spillovers which reduce the entrant's investment costs in areas where the incumbent has already invested (e.g. by reduced administrative and contractual costs).

In their analysis, Bourreau et al. (2011) distinguish two scenarios: One in which the next generation network is left unregulated, and one in which the regulator mandates access to it.

access price are high enough, the firm will decide to invest.

Though, there is mandated access to the legacy network in both cases. In any case, the access price is set ex-ante.

The new infrastructure is not subject to access regulation

They first consider the scenario of an unregulated next generation network. The entrant's incentive to invest in an own network is influenced by the presence of spillovers. If they are high, the entrant will also invest in those areas where the incumbent has already invested. In contrast, if they are low, the entrant is less likely to mimic the incumbent's coverage. Clearly, the access price can induce further investment by the entrant. A higher access price for the legacy network decreases the opportunity costs of investing for the entrant (replacement effect). Therefore, its investment is more likely and the entrant might also roll out a next generation network in areas where the incumbent has not yet invested.

On the other hand, the level of the access price also affects the incumbent's incentives. In the case of high spillovers, the incumbent faces the dilemma that when he invests the entrant will also invest. As a result, the incumbent will lose access charge revenues in those areas since the entrant will then no longer seek access. Bourreau et al. (2011) call this the wholesale revenue effect. A higher access price for the legacy network represents higher opportunity costs of investing for the incumbent as he then would forego these profitable access charge revenues. Accordingly, he is less likely to invest.

In addition, a low access price might also reduce the incumbent's investment. A low access price for the legacy network implies low retail prices for the respective services. This, in turn, might reduce the profitability of the new network as relatively low retail prices for the next generation network would be required to induce consumers to switch. Bourreau et al. (2011) refer to this as the business migration effect.

Clearly, a high access price has the ability to enforce the entrant's investment. Yet, a high access price also implies lower consumer welfare in areas where no next generation network is rolled out (due to accordingly higher retail prices). Taking this trade-off into account, Bourreau et al. (2011) use simulations and show that the optimal access price has to increase with the level of spillovers. Thus, the entrant's investment can be ensured which is otherwise less likely to occur as the entrant makes its investment dependent on the incumbent's investment in order to benefit from spillovers. The incumbent anticipates the accordingly reduced wholesale revenues and invests less which, in turn, reduces also the entrant's investment. The obvious way to trigger more investment by the entrant is to reduce its opportunity costs of investing by setting ex-ante a higher access price for the old

network.

The new infrastructure is subject to access regulation

Regarding the second scenario, access is now also mandated on the next generation network and affects whoever has rolled out the new infrastructure. Bourreau et al. (2011) state that this mandated access leads, in general, to less investment. The prospect of granted access to the new network can reduce the entrant's investment incentives as it might find it more profitable to seek access.[18] Additionally, the firm mandated to provide access might face reduced profits from its investment. This, of course, depends on the level of the access price for the next generation network. If it is high enough, it can indeed trigger more investment. On the one hand, the investor would get enough access charge revenues to recover its investment costs. On the other hand, while facing high access fees the entrant might find it less attractive to seek access and might invest in its own infrastructure.

Hence, the regulator faces a trade-off. Either, he could set ex-ante a high access price for the new network and, thus, increases the further roll-out of new infrastructure. Or, he could establish a low access price for the new network in order to enhance static efficiency (i.e. reduce consumer welfare losses) if he expects that only one new network will be rolled out.

Yet, Bourreau et al. (2011) stress that this access price is interrelated to the one for the legacy network. They show this by focusing on the case in which the incumbent is expected to have rolled out new infrastructure in more areas than the entrant.[19] This implies that the incumbent possesses in fact a monopoly infrastructure and the regulator might be motivated to accordingly set a low access price for the new network to increase static efficiency. Yet, it is to keep in mind that in this regime with mandated access to the new network investment is generally lower and, hence, the regulator might already have set a high access price for the old network to reinforce investment. However, as described above, a higher access price for the legacy network also lowers consumer welfare in areas where no next generation network will be rolled out (assuming that the same access price applies in every area). With the possibility to gain access to the newly rolled out network at a low access fee, access will be sought by the entrant. Yet, this reduces any further investment incentives of the incumbent. Thus, there might be no further reduction of areas without next generation networks. These areas will especially continue to encounter reduced consumer welfare due to the high access price. Hence, there is rather an incentive for the regulator to enforce investment in next generation networks by the entrant. Therefore, he would rather set ex-ante a higher access price for the new

[18] Conversely, it is also possible that the incumbent seeks access to the entrant's newly rolled out network, if he considers this to be more profitable than rolling out his own new network.
[19] The symmetric case is irrelevant since there is no need to seek access as both firms employ their own infrastructure.

network thereby making access seeking less attractive and investment in an own next generation network more likely.

Accordingly, there seems to be a positive correlation between both access prices. If the access price for the legacy network was low and the regulator wished to enforce migration to the new network, this would then necessitate a low access price for the new network in order to make the entrant switch.

Still, in the case in which the entrant is expected to have rolled out new infrastructure in more areas than the incumbent, Bourreau et al. (2011) show that a negative correlation between both access prices could emerge. A high access price for the legacy network induces the entrant to invest in its own new infrastructure, which indeed entails the situation in which the entrant possesses more monopolistic infrastructure to which the incumbent seeks access. Hence, the regulator could now increase consumer welfare in these areas by setting a lower access price for the new network. This is possible, in contrast to the previous case, as no more investment by the entrant is intended. Indeed, a low access price for the entrant's infrastructure might encourage more access seeking to it by the incumbent. (Of course, a higher access price for the entrant's new infrastructure might also induce more investment by the incumbent. Yet, they state that the incumbent's investment decision is less sensitive to the access price than the entrant's decision. Hence, an even higher access price would be necessary. This, however, is even more at the expense of consumer welfare in areas where only one next generation network will prevail.)

A.5.2 Bourreau et al. (2014)

Especially the afore-mentioned result (see section A.4.1) of the interrelation of both access prices is confirmed by Bourreau et al. (2014). They employ a similar but more general framework, in which they neglect spillovers so that both firms face the same (area-dependent) investment costs and marginal costs. Though, the incumbent is assumed to invest first.

To recap, they find that the connection between both access prices is dependent on which firm is expected to have rolled out new infrastructure in more areas than the other firm. If the incumbent is expected to cover more areas than the entrant, there is a positive correlation. A high access price for the legacy network requires a high access price for the next generation network in order to enforce more investment by both firms. This enlarges the areas with two new networks and reduces those with only one new network. Thereby it effectively limits the areas with monopolistic infrastructure where consumers are exposed to high retail prices (resulting from high access prices which are passed on to them). In contrast, if the entrant is expected to cover more areas than the incumbent,

there is a negative correlation. A high access price for the legacy network might entail a low access price for the next generation network in order to moderate further investment by the entrant and to reduce consumer welfare losses in areas with only one new network.

Yet, Bourreau et al. (2014) remind that the ex-ante setting of access prices which take this interrelation into account requires good anticipation and/or knowledge of which firm will dominate the investment in new infrastructure. Therefore, the practical implementation might be limited.

Moreover, Bourreau et al. (2014) note that switch-off obligations for the legacy network can force migration to the next generation network. This, in turn, gives the regulator more flexibility when setting the access price for the new network as he is no longer required to take into account the interrelation between both access prices.

The new infrastructure is not subject to access regulation

In their analysis, Bourreau et al. (2014) also examine more closely the case in which the next generation network is not regulated. Here, they deviate from former studies and introduce the possibility of geographically differentiated access prices for the legacy network which depend on whether or not an alternative next generation network has been rolled out in the area. Such an access price regime is only relevant for the case in which the incumbent has rolled out new infrastructure in more areas than the entrant.[20] They show that such geographically differentiated access pricing can outperform uniform pricing but is still not able to arrive at the first-best solution. With uniform access prices the regulator has to trade off static efficiency against investment incentives. That is, a higher access price for the legacy network can induce more investment in new infrastructure by the entrant but only at the expense of high retail prices in areas where the entrant still continues to seek access to the incumbent's legacy network.

The regulator could solve this tension by ex-ante mandating a cost-oriented access price for the legacy network in areas where no new infrastructure exists and an above-cost access price in the remaining areas. (No access price is necessary in areas where both parties have invested in new infrastructure.) Thus, there will be enhanced static efficiency in areas where the entrant seeks access to the legacy network (due to non-deteriorated retail prices) and also optimal investment incentives in the other areas. Yet, one drawback remains. The higher access price might enlarge the areas with two new networks, but those areas where only one new network has been rolled out will expose reduced static efficiency (as the entrant continues to seek access to the old network and passes the

[20] In the opposite case, the entrant only seeks access to the incumbent's legacy network in areas where no new infrastructure exists. In the remaining areas, it does not seek access to the incumbent's new network as it has its own new network. Hence, such a distinction is not necessary.

above-cost access price on to the consumers).

A.5.3 Brito et al. (2012)

Brito et al. (2012) study the incentives of an incumbent to invest in next generation infrastructure and to grant access to it. They model a strategic interaction between a vertically integrated incumbent owning the legacy network and an entrant which accesses the legacy network. The access price for the old network is set ex-ante by the regulator, but the new network remains unregulated. Moreover and in contrast to Bourreau et al. (2011), there are no spillovers from the incumbent's investment. The entrant is rather assumed to have higher investment costs than the incumbent. This means that the entrant will not invest. However, this assumption is relaxed later. Moreover, they do not model different areas. Thus, investment costs are area-independent. Yet, they distinguish whether the technology of the new infrastructure represents a drastic or a non-drastic innovation.

The new infrastructure is a non-drastic innovation

A non-drastic innovation implies that with a sufficiently low access price for the legacy network the entrant will still be able to compete with the incumbent employing the new technology. In this case and assuming that the entrant cannot invest, the access price will have the following implications. If the access price is set high, this deteriorates the entrant's ability to compete with the incumbent as the entrant's services are more expensive. The incumbent has therefore an incentive to invest as he does not fear any competition from the entrant which employs the old network. In order to reinforce his profitable position, he would further foreclose the entrant by denying access. Thus, he would become a monopolist on his new network. By investing the incumbent would indeed forego the profits from access charge revenues. Yet, consumers value the quality of the new network which eventually translates to retail profits which can outweigh these foregone profits.

In contrast, if the access price is low, the entrant is able to compete. The incumbent will then grant the entrant access to his new network. This motivation stems from the following effects. On the one hand, the incumbent will face reduced retail profits when competing with the entrant on the new infrastructure. On the other hand, since he is able to set an own access price for his new network, he can set it in such a way that he gets profitable access charge revenues. The latter profits can outweigh the former losses and the incumbent will grant access at such a price which warrants high enough profits and also ensures access seeking by the entrant. Yet, Brito et al. (2012) point out that at an intermediate access price the incumbent might not invest. The possible gains from the aforementioned access charge revenues might not suffice to make up for the stronger ex-post

competition as well as for the foregone profits from access charge revenues which result from the access price for the old network.

Brito et al. (2012) also discuss the case in which none firm has an investment costs disadvantage. If investment cost are low, both firms might invest. An access price for the old network is then redundant. If investment cost are high, investment will always be conducted by one firm (which depends on some technical conditions). If it is the incumbent which invests, the description above applies. However, if it is the entrant which invests, it will always grant access to the incumbent. This results from the fact that with a non-drastic innovation, the incumbent is always able to compete with the new infrastructure although employing his old network since his costs on it are not distorted by any access price.

Brito et al. (2012) then derive the implications for an optimal access price which maximizes social welfare, i.e. the sum of consumer and producer surplus. In the case in which only the incumbent can invest, the optimal access price depends on the quality improvement of the new technology, which increases the valuation of consumers. If it is small, the access price should be set at marginal costs in order to enforce that the incumbent rolls out a new network and grants access to it (since, as described above, with a low access price the entrant is able to compete with the incumbent). If it is large, the regulator should set such a high access price that a monopoly on the new network emerges. They argue that such a monopoly would be socially desirable as the welfare loss caused by the existence of a monopolistic incumbent might be smaller than the welfare loss caused by increased retail prices resulting from a high access price. Yet, this is a result of quite restricting conditions: The entrant is not able to attract new consumers, is less efficient than the incumbent and the monopoly deadweight loss[21] is small. This implies that the retail price for the entrant's service is distorted upwards (as the incumbent only grants access at a high access price and the entrant fully passes it on to consumers) and consumers would be better off not buying at such inflated prices.

In the case in which both firms can invest, the regulator is not able to influence the equilibrium outcome by changing the access price for the old network. Brito et al. (2012) state that social welfare cannot be increased if investment costs are so high that only one firm invests. If, in contrast, investment costs are low, both firms always invest and do not rely anymore on the access price for the old network.

[21] The deadweight loss can be defined as the loss in the sum of consumer and producer surplus in a monopoly situation compared to a market with perfect competition.

The new infrastructure is a drastic innovation

Finally, if the technology of the new network represents a drastic innovation, the incumbent always invests (since he has lower investment costs). He further always denies access to the entrant as he does not fear any competition from the entrant employing only the old network. The regulator cannot influence this as even if he sets the access price for the old network at marginal costs, this cannot put the entrant in a competitive position since the quality differential between both networks is too large.

A.6 Investment incentives under asymmetric access regulation

A.6.1 Matsushima and Mizuno (2012)

Matsushima and Mizuno (2012) model a market situation of two facility-based firms and one entrant, which seeks access to one of the former firms, the incumbent. The other facility-based firm does not provide access to the entrant nor is it mandated to do so. Matsushima and Mizuno (2012), therefore, depict an asymmetric access regulation. In their study they compare how the presence of an additional facility-based firm alters the incumbent's incentives to invest and to foreclose the entrant. They further analyse how the investment incentives of the other facility-based firm are affected.

They employ two important assumptions. First, both facility-based firms employ the same production and investment technologies, i.e. even though only one firm is subject to access regulation, both firms do not differ otherwise. One could think of a DSL incumbent and a cable operator which offer comparable services to consumers. Second, any investment is demand-enhancing, but the incumbent's investment partly benefits the entrant, whereas the other facility-based firm's investment does not. This crucially affects the incumbent's behaviour.

In the case of access regulation at a cost-based access price, the incumbent has a weakened incentive to invest as his investment also benefits the entrant. Yet, with the presence of a facility-based competitor the incumbent's investment also has a strategic effect: The incumbent gains from his investment as he can attract consumers away from the competitor. Therefore, Matsushima and Mizuno (2012) state that his investment is always higher than when the facility-based competitor is absent. However, the incumbent's investment is lower than the facility-based firm's as the incumbent's investment benefits the entrant and the incumbent is unwilling to support it in that way. In addition, since the access price is mandated at a cost-based level, foreclosure of the entrant does not occur.

The case without access regulation

In contrast, without access regulation, the incumbent can decide to voluntarily grant access to his infrastructure and can then freely set the access fee (i.e. he could also foreclose the entrant). The strategic effect of the incumbent's investment then plays an important role. Even though his investment benefits the entrant, the incumbent would invest since he is then able to stipulate such an access price that he absorbs profits from the entrant. Matsushima and Mizuno (2012) state that the incumbent, thus, uses the entrant as his affiliate to compete with the facility-based firm. For the very reason that the incumbent's investment benefits the entrant (and enables it to attract more consumers), both together can attract consumers from the facility-based competitor. The investment might even be higher than that of the facility-based firm if the beneficial spillovers are sufficiently high.

Accordingly, the presence of a facility-based competitor and of possible spillovers to the entrant enhance the incumbent's investment incentive when there is no access regulation. Compared to the case with access regulation, the investment by the incumbent is even higher.

Moreover, as became clear, without access regulation the incumbent's incentive to foreclose the entrant is also weakened. He might only decide to foreclose the entrant if the spillovers are small or investment costs are low. In this case, the facility-based firm more easily invests so that there is more competitive pressure on the incumbent. Yet, as the entrant hardly benefits from the incumbent's investment, it cannot considerably attract more consumers, which means that by granting access the incumbent cannot increase his access charge revenues at the expense of the facility-based firm. Thus, the incumbent rather forecloses the entrant in order to have one competitor less. Additionally, the entrant might not even be able to compete with the facility-based firms, which have enhanced their qualities of service by means of investment, and it accordingly no longer seeks access.