How to provide access to next generation networks? 
Different regulatory regimes and their effects on investments

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In this paper, I analyze the incentives to invest in Next Generation Access Networks (NGA) by modeling price competition between an investing and an access seeking firm with horizontal product differentiation. Given an uncertain success of the NGA, I compare two different regulatory regimes, one with symmetric and one with asymmetric risk allocation, with the opportunity that firms cooperate and jointly roll-out the NGA. I find that private incentives to cooperate mostly coincide with the consumer surplus maximizing outcome. Whether the firms realize this socially desirable outcome depends on the outside option, i.e. the implemented access regime. The optimal regulatory policy is not only subject to the probability that the NGA succeed but even more to the degree of product differentiation in the retail market.

Keywords: Next Generation Access Networks, investments, access regulation, cooperation
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1 Introduction

Currently, there is a broad discussion about the deployment of Next Generation Access Networks (NGA) in the telecommunications markets. Due to the importance of telecommunications infrastructures for economic growth,\textsuperscript{1} the European Commission set ambitious targets regarding the coverage with “ultra-fast broadband” infrastructures.\textsuperscript{2} The roll-out of new access fiber networks and the replacement of (large parts of) the existing copper networks, which represented the core telecommunication infrastructure for decades, change the requirements for regulation. The main objective shifted from the optimization of allocative efficiency, i.e. the introduction of competition, to more dynamic aspects, i.e. the question how to stimulate investment incentives while ensuring an adequate level of competition.\textsuperscript{3}

In general, investing firms face two different kinds of risk, market risk and regulatory risk. The market risk describes the uncertainty whether the new infrastructure and emerging services generate sufficient demand and willingness to pay to amortize the carried out investments. Dealing with market risk is a typical task of firms in innovative markets and broadly discussed especially in the R&D literature.\textsuperscript{4} The difference in network industries is the existence of regulatory constraints.\textsuperscript{5} The regulatory risk describes the risk that sunk investment costs are not sufficiently considered by regulatory authorities.\textsuperscript{6} In the context of NGA and the existing market risk, this problem is of great importance. In particular, there is a risk that investment costs are only taken into account if the new infrastructure succeeds, i.e. if there is sufficient demand, and that the investing firm has to bear all costs if the NGA fails. Hence, there is a risk of an asymmetric risk allocation between investing and access seeking firms. In view of these risks and the extensive investment requirements related to the NGA roll-out, the opportunities of cooperation and joint investments in the network of firms, which compete in the retail markets, have become a more important topic recently.

Given these aspects, the challenge for today’s regulation is the promotion of sufficient investment incentives while maintaining an adequate level of competition. The New Regulatory Framework\textsuperscript{7} addresses these challenges and allows the introduction of some regulatory instruments which make a better consideration of the risk related to investments in new infrastructures and the trade-off between static and dynamic efficiency possible. In general, the private and social incentives to provide the new infrastructures do not differ fundamentally as firms have

\textsuperscript{1}Cf. Röller & Waverman (2001), Czernich et al. (2009) or Katz et al. (2010).
\textsuperscript{2}Cf. Commission of the European Communities, Commission of the European Communities (2010b).
\textsuperscript{3}As Laffont & Tirole (2001, p.7) pointed out, there exists a Schumpetrian trade-off between static efficiency, i.e. an intense (service-based) competition with a given infrastructure and encouraging investments ex ante.
\textsuperscript{4}Cf. Dixit & Pindyck (1994) for a general discussion of uncertain investments.
\textsuperscript{6}Guthrie (2006) provides a comprehensive overview of the effect of different regulation regimes and their impact on investment incentives in network industries with emphasis on regulatory risk.
\textsuperscript{7}Cf. Directive (2009/140/EC).
incentives to tap into new markets. Hence, an important question is how the regulatory framework might support and foster the private investment incentives such that socially desirable objectives might be achieved with a minimum of regulatory interventions.

In economic literature as well as in practice, the effects of regulation on investment are heavily disputed. In this paper, I focus on a recent work of Nitsche & Wiethaus (2010) and adjust their basic framework by considering additional aspects. Nitsche & Wiethaus (NW hereafter) compare four different regulatory regimes regarding the effects on investment incentives, the competition intensity and the resulting consumer surplus in a two-staged Cournot model with two firms, a vertically integrated incumbent and an access seeking entrant. The main contribution of their paper is the linkage between the extent of investment and the access price. Similar to Klumpp & Su (2010), the access price considers total investment costs as well as the firms’ usage of the new infrastructure. In the presence of uncertainty regarding the success of the NGA, NW compare long run incremental cost regulation (LRIC), a regime with asymmetric risk allocation in which the entrant only bears part of the investment costs if the NGA is a success, to three alternatives. First, NW include a full distribution of costs regulation (FD) with symmetric risk allocation in which the entrant bears part of the investment costs even if the NGA fails. Second, they include a risk sharing regulation (RS) in which both firms jointly deploy and use the new infrastructure without any further access fees. Third, they considered regulatory holidays (RH), i.e. a regime in which the incumbent has no access obligations.

NW’s results are three-part: First, for a given investment level risk-sharing yields the highest competitive intensity, i.e. the highest expected total quantity, and LRIC performs better than full distribution. Second, the investment incentives are highest with full distribution and regulatory holidays followed by risk-sharing and LRIC. Third, the consumer surplus is maximized with the risk-sharing regime. Full distribution always outperforms LRIC and regulatory holidays might be worse than LRIC if the probability of success of the NGA is relatively high.

In the following, I adjust NW’s model regarding several aspects. The main difference is that I assume price competition in the retail market. This seems more realistic as one might observe an intensive price competition in most European broadband access markets. Especially the fierce service-based competition seems to be an obstacle for investments in NGA as new services are rarely available yet and therefore new access networks compete directly with the old technologies. Moreover, investments in telecommunications infrastructures, such as a fiber or cable network, are typically characterized by high sunk investment costs and the opportunity to serve all consumers connected to the infrastructure in a specific area. Hence, the firms’ ex post behavior is driven by these two aspects and competition is more about the utilization of

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8Cf. Cambini & Jiang (2009) for a comprehensive overview of empirical as well as theoretical studies regarding the effects of regulation on investment in broadband markets.

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the infrastructure then about a capacity choice.\footnote{Cf. Kahn (2006).} Another additional aspect in my model is the consideration of horizontal product differentiation. The motivation for this setup is twofold. First, even if the firms compete in the same market, retail products are no perfect substitutes by itself but horizontally differentiated. Either consumers might have preferences for firms or firms might provide different services, e.g. additional services such as IP-TV, Video on demand etc. Second, there is an increasing amount of firms from different infrastructure industries, such as telecommunications and electricity supplier, who jointly roll-out new infrastructures. Especially the discussion about smart grids and their roll-out yields an interest in telecommunication services combined with other services, e.g. smart metering. Considering that the main costs related to the roll-out of new infrastructures result from excavation work, there exists huge synergy and cost saving potential if firms cooperate. In this context, access to the infrastructure might also be interpreted as access to ducts of other infrastructure providers. Based on this argumentation, another adjustment of NW’s model is the interpretation of their risk-sharing regime. As firms jointly deploy and use the infrastructure without any further access costs, I interpret this setup explicitly as cooperation between firms. This has two effects on the modeling: First, an important question is whether the firms are willing to cooperate as they could not be forced to do so by regulatory authorities. Therefore, I introduce another game stage in which the firms decide whether to cooperate or not given the implemented access regime. Moreover, I consider a positive payment from the entrant to the incumbent in this setup, i.e. the entrant bears half of the investment costs.

Given this adjustments and extensions, the results partly differ from NW’s findings and gives some further insights. Regarding the competition intensity on the retail market, NW’s results apply. The first difference concerns the investment incentives. As in the model of NW, full distribution yields higher investment incentives as LRIC. For highly differentiated retail products, cooperation might yield higher investments as full distribution. In comparison with LRIC, cooperation yields higher investments for most parameter values and in particular if the investment is risky. Considering perfect substitutes in the setup with price competition explains the weak investment incentives with LRIC regulation as this yields to a situation without investment. Regarding the cooperation decision, the analysis shows that the incentives to cooperate differ significantly if the entrant participates in the investment risk. In NW’s risk-sharing setup, in which the entrant does not make any side payment and therefore does not bear any risk, firms will never agree to jointly build the infrastructure. The reason for this behavior are opposing incentives for the incumbent and the entrant. In my setup in which the entrant bears half of the investment costs, cooperation might be preferred from both firms especially if the retail products are heterogeneous and if the success of the NGA is highly uncertain. The analysis of the consumer surplus shows that the optimal regulatory policy is subject to the degree of
product differentiation and the probability of the success of the NGA. In opposite to NW, risk-sharing is not always the superior regime as cooperation as well as full-distribution might yield higher consumer surplus. While the implementation of LRIC seems favorable especially if the success of the infrastructure is relatively certain, cooperation seems best if products are relatively heterogeneous. Whether cooperation is realized is subject to the outside opportunity, i.e. the realized access regime. Thereby, the private incentives to cooperate might coincide with the consumer surplus maximizing outcome.

The remainder of the paper is as follows. Section 2 provides the basic setup of the model and explains the game in more detail. In Section 3, I derive the equilibrium conditions by solving the subgames of the model recursively. Section 4 concludes.

2 The model

In the Model, I examine a market with two firms, an incumbent denoted by $I$ and an entrant denoted by $E$. Both firms compete in the Internet broadband access market using a given technology, e.g. DSL, with horizontally differentiated goods. The incumbent might invest in a Next Generation Access Network (NGA) and the entrant gets (regulated) access to the incumbent’s network for an access fee $\alpha$. The roll-out of the new infrastructure is risky as the demand for new services and therefore the infrastructure’s success is uncertain. With probably $\beta$, consumers will ask for new services based on this infrastructure and with probability $1 - \beta$ consumers prefer service which could be provided with the old network.

2.1 Demand

The entrant’s and the incumbent’s retail demands, $q_E$ and $q_I$, are derived from a representative consumer with the following linear-quadratic utility function:\footnote{For a detailed description, see Vives (2001, p.145-147). Note that I abstract from the numeraire good.}

$$U = (\nu + \psi x)q_I - \frac{q_I^2}{2} + (\nu + \psi x)q_E - \frac{q_E^2}{2} - \sigma q_I q_E$$  

(1)

The consumer’s reservation utility for broadband access is given by $\nu$. For simplicity, let us assume that the reservation utility is the same for both products. The parameter $\psi$ reflects the success of the NGA. With probability $\beta$, there is a demand for new services and products based on the NGA and $\psi$ equals 1. In this case, the demand increases by the extent of the investment $x$. If there emerge no new services and consumers keep using the common technology, $\psi$ equals 0 and the consumers do not have an additional utility from the new infrastructure. The probability of such a fail of the new technology is $1 - \beta$. The extent
of the NGA investment $x$ might be interpreted as different NGA technologies, e.g. fiber-to-the-cabinet (FttC), fiber-to-the-building (FttB), or fiber-to-the-home (FttH), which allow for different bandwiths and therefore different service. The (horizontal) product differentiation is represented by the parameter $\sigma \in [0, 1]$, whereas $\sigma$ equals 1 for homogeneous and 0 for independent goods.

Maximizing the utility subject to the budget constraint yields the demand functions

$$q_I = \frac{\nu - p_I - \sigma(\nu - p_E)}{1 - \sigma^2} + \psi \frac{x}{1 + \sigma}$$

$$q_E = \frac{\nu - p_E - \sigma(\nu - p_I)}{1 - \sigma^2} + \psi \frac{x}{1 + \sigma}$$

The demand of each firm increases with the consumer’s willingness to pay for broadband access $\nu$, with the degree of the product differentiation $\sigma$, and with price of the competitor and decreases with the firm’s own price. If the investment is a success, i.e. for $\psi = 1$, the demand increases with the extent of the NGA roll-out $x$ weighted with the extent of product differentiation. If the NGA is a failure, i.e. $\psi = 0$, the investment in the NGA has no effect on the demand.

### 2.2 Access regime

A crucial point regarding the investment incentives is the regulatory framework and existing access obligations. In the following, I use two different regulatory setups introduced by Nitsche & Wiethaus (2010, NW hereafter), i.e. (i) long-run incremental costs regulation and (ii) full distribution of costs regulation, in order to compare the investment incentives as well as the effects of these regimes on competition. Moreover, I adjust NW’s (iii) risk-sharing regulation to a setup with cooperation.

The *long-run incremental costs regulation (LRIC)* only take costs of the currently used network into account. In this setup, this means that the investment costs are only included in the access fee if the NGA succeeds. Within this regime, one of the main problems related to investments in NGA is revealed, i.e. the asymmetric allocation of risk between investing and access seeking firms. If the NGA fails, competitors will not ask for access to the new network and the investing firm bears all investment costs alone. In the case that the NGA becomes a success, other firms might ask for access and the regulator takes the investment costs into account. Hence, there is an asymmetric allocation of the investment risk between the investing and the access seeking firms.

In the *full distribution of costs regulation (FD)*, the investment costs related to NGA are taken into account even if the NGA is no success and ensures a symmetric risk allocation. The access seeking firm has to bear part of the investment costs even if the NGA fails and
the firm does not ask for access to the new infrastructure. This might either be interpreted as a consideration of the investment costs in the access fee for the old infrastructure, e.g. the price for local loop unbundling, or as consideration of the investment costs in the case of virtual unbundling, i.e. the provision of virtually unbundled wholesale access based on the new technology.

The third regime considered is a cooperation between the firms (CO). If the firms decide to jointly invest in the infrastructure, the entrant bears part $\mu$ of the investment costs with a fixed payment to the incumbent prior to investment and is allowed to use the infrastructure without any further access payment. I will consider two cases of fixed payments. First, I will follow NW and assume $\mu = 0$ in order to compare my finding with their results. Thereafter, I will assume that the firms equally share the investment costs, i.e. $\mu = \frac{1}{2}$. This case could be interpreted as a cooperation in which each firm builds its own local network as a local monopolist and both firms get access to the other firms’ infrastructure on a bill-and-keep basis. The investment decision in the cooperation case differs from the two regimes above. With regulated access, the incumbent will only consider its own expected profits in its investment decision. If both firm cooperate, the investment decision is made such that the joint profits of both firms are maximized given competition in the retail market.

The access price is borrowed from Nitsche & Wiethaus (2010, p.3) and given by

$$w_{\ell,\varrho} = \alpha_{\ell,\varrho} \frac{f(x)}{q_I + q_E}$$

where $\varrho = L, FD, CO$ represents the installed regime, $\alpha_{\ell,\varrho} = 0, 1$ is a regulatory parameter defining whether the investment costs are considered in the access fee, $\ell = S, F$ represents whether the NGA is a success or not, $f(x)$ are the investment costs for an deployment $x$, and $q_j$ are the quantities of the firm $j = I, E$. Similar to Klumpp & Su (2010), this setup endogenizes the investment costs in the access fee and neither a commitment problem nor foreclosure are problematic. Moreover, as we will see, this access fee setup ensures that both firms face the same access costs on the downstream market.

An overview of the parameter settings and maximization problems at the investment stage subject to the regulatory regimes is presented in Table 1.

<table>
<thead>
<tr>
<th>Regime, $\varrho$</th>
<th>Access parameters</th>
<th>Fixed investment participation</th>
<th>Maximization problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>LRIC, L</td>
<td>$\alpha^S = 1, \alpha^F = 0$</td>
<td>$\mu = 0$</td>
<td>$\max_{p,x} E(\pi_I)$</td>
</tr>
<tr>
<td>Full distribution, FD</td>
<td>$\alpha^S = 1, \alpha^F = 1$</td>
<td>$\mu = 0$</td>
<td>$\max_{p,x} E(\pi_I)$</td>
</tr>
<tr>
<td>Cooperation, CO</td>
<td>$\alpha^S = 0, \alpha^F = 0$</td>
<td>$\mu = 0, \frac{1}{2}$</td>
<td>$\max_{p,x} E(\pi_I + \pi_E)$</td>
</tr>
</tbody>
</table>

Table 1: Regulatory regimes and parameter settings
2.3 Firm’s profit maximization

In this setup, I assume a vertically integrated incumbent, which profit consists of two parts, i.e. its profit from the downstream division and its profit from the upstream division. On the upstream market, the incumbent’s expected profit is given by

$$E(\pi_U^I) = \beta w^S(q^S_I + q^S_E) + (1 - \beta)w^F(q^F_I + q^F_E) - (1 - \mu)f(x).$$  \hspace{1cm} (3)$$

The access payments from the downstream market in the different regimes are weighted with the probability that the NGA succeeds $0 < \beta < 1$ or fails $1 - \beta$. Moreover, the upstream unit has to bear the part of the investment costs $f(x)$ reduced by the portion $\mu$, i.e. the part of the investment costs covered by a fixed payment of the entrant if both cooperate. The costs for the deployment of the NGA are assumed as $f(x) = \frac{\gamma}{2}x^2$. I model the investment costs as quadratic function to capture the more than proportionally increasing costs in the case that the NGA is rolled-out close to the retail consumers. Note that $f(x) = \frac{\gamma}{2}x^2$ is strictly increasing in $x$ and it applies $f'(x) > 0$, $f''(x) > 0$, $f(0) = 0$, and $f'(0) = 0$. For simplicity, the marginal costs for providing the upstream input are normalized to zero. On the downstream market, the incumbent realizes the expected profit

$$E(\pi_D^I) = \beta (p^S_I - c - w^S q^S_I) + (1 - \beta)(p^F_I - c - w^F q^F_I)$$

with the marginal costs of providing the retail product $c$ and the access fee in the different states and regimes as costs. Consequently, we can write the incumbent’s expected total profit as

$$E(\pi^I) = \beta((p^S_I - c)q^S_I + w^S e q^S_E) + (1 - \beta)((p^F_I - c)q^F_I + w^F e q^F_E) - (1 - \mu)\frac{\gamma}{2}x^2. \hspace{1cm} (5)$$

Hence, the incumbent’s profit consists of its expected revenues from its retail consumers minus the investment costs lowered by the expected access payment from the entrant.

The entrant’s expected profit is given by

$$E(\pi_E) = \beta((p^S_E - c - w^S e)q^S_E) + (1 - \beta)((p^F_E - c - w^F e)q^F_E) - \mu\frac{\gamma}{2}x^2. \hspace{1cm} (6)$$

For simplicity, let us assume an equally efficient entrant with identical marginal costs $c$ for providing the retail product. If the firms decide to cooperate, the entrant bears the fixed part of the investment costs $\mu\frac{\gamma}{2}x^2$ prior to investment.
2.4 Timing of the Game

The game consists of four stages and the timing is as follows:

1. **REGULATION**
   The regulator sets the access regime.

2. **FIRMS’ COOPERATION DECISIONS**
   Firms decide whether to cooperate or not.

3. **INVESTMENT STAGE**
   The incumbent choose its investment level, i.e. the extend of the NGA roll-out.

4. **PRICING STAGE**
   Both firms set their prices simultaneously and compete in the market.

In the first stage, the regulator credibly commits to a regulatory policy, i.e. LRIC or FD. As the regulator sets the access regime ex ante, no commitment or hold-up problem occurs.

In the second stage, the firms decide whether to cooperate or not. The firms will only chose this opportunity if the profit of each firm is higher compared to a situation with regulated access. If at least one firm refuses to cooperate, access is provided with the given regulatory access regime.

In the third stage, the incumbent maximizes its total expected profits via the extent of the NGA roll-out. Remember that the incumbent will maximize the expected joint profits of the firms if both agree to cooperate given the competition on the downstream market.

In the fourth stage, both firms compete in prices. This seems to be in line with the observations in most retail broadband access markets. Considering the large amount of firms which compete in this market, one might assume a high competitive pressure. Moreover, telecommunications infrastructures are typically characterized by high sunk investment costs, low marginal costs for providing services and and the opportunity to serve a range of consumers in a specific region.\(^{11}\) Hence, firms have rather an incentive to compete very aggressively if the infrastructure is in place to utilize the build capacities.\(^{12}\)

3 Equilibria

In the following subsections, I solve the four stages of the game recursively in order to find the subgame perfect Nash equilibrium.

\(^{11}\)For instance, the upgrade of a local area interface and enables the provision of FttC services to all consumers connected to this interface.

\(^{12}\)See also Kahn (2006, p.161 sqq.) for a similar argumentation.
3.1 Pricing stage

In the last stage of the game, the firms maximize their profits with respect to the price given the extent and the success of the NGA roll-out and given the regulatory regime, i.e.

\[
\max_{p_I} \pi_I = (p_I^\ell - c)q^\ell_I + w^\ell q^\ell_E
\]

\[
\max_{p_E} \pi_E = (p_E^\ell - c - w^\ell)q^\ell_E
\]

with \(\ell = S, F\) and \(\varrho = L, FD, CO\) As the investment costs are already sunk in the pricing stage, they are not considered in the profit maximization problem of the firms in this stage of the game.

Differentiating the profit functions with respect to the prices yield the first order conditions

\[
\frac{\partial \pi_i}{\partial p_i} = \frac{\nu + c - 2p_i - \sigma(\nu - p_j)}{(1 - \sigma)^2} + \psi x \frac{1}{1 + \sigma} + \alpha^\ell \gamma x^2 \frac{(1 + \sigma)(\nu + \psi x - p_j)}{2 (1 - \sigma)(2(\nu + \psi x) - p_i - p_j)} = 0
\]

with \(i, j = I, E\) and \(i \neq j\). Note that the firms have the symmetric first order conditions. This finding might be not intuitive at first sight but becomes clear if we reconsider the incumbent’s profit functions on the upstream and on the downstream level, i.e. equations (3) and (4).

On the downstream level, the incumbent’s and the entrant’s profit functions are symmetric. Reconsidering equations (4) and (6), it becomes clear that both firms face the same marginal costs, i.e. the costs for providing the service and the access fee. On the upstream level, we can substitute \(w^\ell\) in the incumbent’s profit function, equation (3), and rearrange it to

\[
E \left( \pi^U_I \right) = \beta w^S(q^S_I + q^S_E) + (1 - \beta)w^F(q^F_I + q^F_E) - (1 - \mu)f(x)
\]

\[
= -\frac{\gamma x^2}{2} \left( 1 - \mu - \beta \alpha^S - (1 - \beta)\alpha^F \right)
\]

The incumbent’s expected profit on the upstream market is independent from its own downstream quantities. Consequently, the incumbent only maximizes its downstream profits on this stage of the game. As the incumbent faces the same costs and the same reservation utility as the entrant, both first order conditions are symmetrical.

Solving the first order conditions with respect to the prices yield the equilibrium prices in the case \(\ell = S, F\) given the regulatory regime \(\varrho = L, FD, CO\)

\[
p^\ell_{I, I}^{\ast} = \frac{(c + (3 - 2\sigma)(\nu + \psi x)) - \sqrt{(\nu + \psi x - c)^2 - \frac{1}{2} \alpha^\ell \gamma x^2(2 - \sigma)(\sigma + 1)^2}}{2(2 - \sigma)}
\]
where $\psi = 1$ if the NGA succeeds and $\psi = 0$ if the NGA fails. The value of the access parameter $\alpha^\ell\psi$ in the different regimes are as presented in Table 1. Note that the equilibrium prices exist even if the NGA fails, i.e. $\psi = 0$ and the entrant has to bear a part of the investment costs, i.e. $\alpha^F = 1$, as long as $\frac{\gamma x^2}{2} \leq \frac{2(\nu - c)^2}{2}$. This means the investment costs have to be less or equal the total consumer surplus in the worst case.\footnote{As the deployment of the NGA $x$ is negatively related to the investment cost parameter $\gamma$, i.e. if $\gamma$ increases, $x$ decreases, this condition seems unproblematic.} The equilibrium prices of both firms increase with the extent of the NGA roll-out $x$ as long as either $\alpha^\ell\psi$ or $\psi$ equal 1. If the NGA is a success, i.e. for $\psi = 1$, the reservation utility of the consumers increase and the firms will increase their prices accordingly. In the full distribution regime, prices will increase with the extent of investment even if the NGA fails, i.e. for $\psi = 0$. In this case, the investment costs are passed to both firms via the access fee, i.e. $\alpha^F,FD = 1$, and the firms adjust their prices to their increasing marginal (access) costs.

Due to the symmetric first-order conditions, both firms charge identical prices in equilibrium. Hence, we get a symmetric equilibrium in which both firms provide the same quantities and charge the same prices. Independent from product differentiation, the result of NW holds with price competition.\footnote{Note that this symmetry does not only hold for two but for $n$ firms as long as the firms face identical costs, identical reservation utilities and the same regulatory regime.}

For homogeneous products, i.e. for $\sigma = 1$, prices equal the firms’ marginal costs in the retail segment, i.e.

$$p_i^\ell|_{\sigma=1} = \frac{1}{2} \left( \nu + \psi x + c - \sqrt{(\nu + \psi x - c)^2 - 2\alpha^\ell\psi \gamma x^2} \right) = c + w^{\ell\psi}|_{\sigma=1}$$

Hence, both firms set their prices equal their marginal costs of providing the retail product $c$ plus the access fee $w$ and the typical Bertrand-outcome for price competition with homogeneous goods applies.\footnote{For an analytical proof of this result, see Appendix A.1.} For $\sigma < 1$, the equilibrium prices contain a mark-up based on the product differentiation.

In order to compare the competitiveness of the different regimes for a given investment level $x$, let us compare the expected prices

$$E(p_i^\ell) = \beta p_i^{S\psi} + (1 - \beta)p_i^{F\psi} \quad (11)$$

and expected total quantities

$$E(Q^\ell) = \beta (q_i^{S\psi} + q_i^{S\psi}) + (1 - \beta)(q_i^{F\psi} + q_i^{F\psi}) \quad (12)$$

with $i = I,E$ and $\varrho = L,FD,CO$.
From the equilibrium prices in equation (10), we can immediately capture two aspects. First, if the firms cooperate, the expected prices are always the lowest. As $\alpha^{FCO} = \alpha^{SCO} = 0$, the value of the square root in equation (10) is always greater than in the other regimes independent from the success of the NGA. This means that both firms face lower marginal access costs on the downstream market if the NGA succeeds and therefore charge lower prices. Hence, the expected prices are below the expected prices in the cases with regulated access. Second, the expected prices in the full distribution regime are always greater than in the $LRIC$ regime. If the NGA succeed, both prices are the same for given investment while prices differ if the NGA fails. With full distribution of costs, $\alpha^{FFD} = 1$ while $\alpha^{FL} = 0$ with a $LRIC$ regulation. Hence, the price reduction based on the square root is lower with full distribution and therefore expected prices are higher. The intuition is straightforward: In the full distribution regime, both firms face higher marginal access costs on the downstream market if the NGA fails and consequently charge higher prices.

Substituting the equilibrium prices in the demand functions yields the equilibrium quantities in the different cases

$$q_{i}^{\theta x^*} = \frac{\nu + \psi x - c + \sqrt{(\nu + \psi x - c)^2 - \frac{1}{2}\alpha^{\theta x} \gamma x^2 (2 - \sigma)(1 + \sigma)^2}}{2(2 - \sigma)(1 + \sigma)}$$

(13)

with $i = I, E$ and $\theta = L, FD, CO$. For a given investment level $x$, the results from above apply analogous. The highest expected quantities are provided with cooperation and the least expected quantities are provided in the full distribution regime.

Based on this intuitive findings, we can note the following proposition:

**Proposition 1.** For $0 < \beta < 1$, $0 \leq \sigma \leq 1$, $\frac{3}{2} x^2 < \frac{1}{4} (\nu - c)^2$,\textsuperscript{16} and a given investment level $x > 0$, it applies

$$E(p_{i}^{CO}) < E(p_{i}^{L}) < E(p_{i}^{FD})$$

$$E(Q^{CO}) > E(Q^{L}) > E(Q^{FD}).$$

**Proof.** See Appendix A.2. ■

Consequently, for a given deployment of the NGA, cooperation yields the fiercest competition while full distribution yields lowest. This result is identical with the finding of NW. Hence, price competition with differentiated goods does not change the competition intensity in these regimes.

\textsuperscript{16}As discussed above, $\frac{3}{2} x^2 < \frac{1}{4} (\nu - c)^2$ is a sufficient condition to ensure that the square root is non-negative. Note that the investment costs might be greater if the NGA is a success, i.e. for $\psi = 1$, or if the investment costs are not passed via the access fee in the failure case, i.e. for $\alpha^{F} = 0$. 

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3.2 Investment stage

In the investment stage, the incumbent chooses the extent of the NGA deployment. Subject to the firms’ decision about a cooperation in the previous stage of the game, the incumbent either maximize its own expected profits or the expected joint profits of both firms.

Let us first consider the case in which the firms disagree to cooperate. The incumbent maximize its expected profits given the access regime and under consideration of the equilibrium prices in the last stage of the game. The incumbent’s maximization problem is therefore given by

$$\max_x E(\pi^v_I) = \beta \left( (p^S_I - c)q^S_I + w^S q^S_E \right) + (1 - \beta) \left( (p^F_I - c)q^F_I + w^F q^F_E \right) - \frac{\gamma}{2} x^2$$

with \( \varrho = L, FD \).

The incumbent maximizes its expected profit with respect to the investment level \( x \) and the first order condition is

$$\frac{\partial E(\pi^v_I)}{\partial x} = \frac{1}{(2 - \sigma)^2 (1 + \sigma)} \left[ \beta (1 - \sigma)(\nu + x - c) \left( 1 + \frac{\nu + x - c}{B^S} \right) \right] - \gamma x \left( 1 - \frac{1}{4 (2 - \sigma)} \left[ \beta \alpha^S \left( \frac{(5 - \sigma)}{B^S} - \frac{(\nu - 2x - c)(1 - \sigma^2)}{B^S} \right) \right] + (1 - \beta) \alpha^F \left( \frac{(5 - \sigma)}{B^F} - \frac{(\nu - c)(1 - \sigma^2)}{B^F} \right) \right) = 0$$

with

$$B^S = \sqrt{\nu + x - c \left[ \frac{1}{2} \alpha^S \gamma (2 - \sigma)(1 + \sigma) \right] - x^2 \alpha^S}$$

$$B^F = \sqrt{\nu - c \left[ \frac{1}{2} \alpha^F \gamma (2 - \sigma)(1 + \sigma) \right] - x^2 \alpha^F}$$

The terms in the first line represent the marginal revenue of the investment in the success case. The terms in the second and third line represent the net investment costs, i.e. the investment costs minus the access fees paid by the entrant.

The first insight is straightforward: If the success of the NGA is certain, i.e. for \( \beta = 1 \), the term in the third line disappears and both access regimes have the same first order condition. Consequently, the optimal investment in both regimes is the same as \( \alpha^S FD = \alpha^S L = 1 \).

As next step, let us consider the case in which the incumbent does not invest. For \( x = 0 \), the
first order condition simplifies to

\[
\frac{2\beta(1-\sigma)(\nu - c)}{(2 - \sigma)^2(1 + \sigma)} \equiv 0
\]  

(16)

From this equation, it becomes obvious that no investment might only be optimal if the retail products are perfect substitutes, i.e. for \(\sigma = 1\), or if there is no probability of success, i.e. for \(\beta = 0\). Note that the presence of perfect substitutes does not necessarily yields no investment if there is a positive probability of success. If we assume homogeneous retail products and substitute \(\sigma = 1\) in the first order condition, we obtain

\[-\gamma x(1 - \beta \alpha^S - (1 - \beta)\alpha^F) \equiv 0\]

In the LRIC regime, i.e. for \(\alpha^S = 1\) and \(\alpha^F = 0\), this condition is only satisfied for \(x = 0\) as long as investment is not costless, i.e. for \(\gamma > 0\). In the FD regime, i.e. for \(\alpha^S = \alpha^F = 1\), the condition is always satisfied and a positive investment level \(x\) might also be optimal. This is a major difference to NW as LRIC yields always positive investment in their setup if there is a positive probability of success. Given very homogeneous products and a very fierce competition on the retail market, the new infrastructure will never be build. Hence, there exists a significant difference between the modeling with Cournot competition and price competition. Additionally, the trade-off between static and dynamic efficiency, i.e. fiercer retail competition with a given infrastructure and incentives to invest in new infrastructures, becomes evident in this case.

Let us now compare the first order condition in both access regimes in general. Subtracting the first order condition in the LRIC regime from the first order condition in the FD regime yields

\[
\frac{\partial E(\pi^F)}{\partial x} - \frac{\partial E(\pi^L)}{\partial x} = \gamma x(1 - \beta) \left( 5 - \sigma - \frac{(\nu - c)(1 - \sigma^2)}{\sqrt{(\nu - c)^2 - \frac{1}{2}\gamma x^2(2 - \sigma)(1 - \sigma)^2}} \right)
\]

If the success of the NGA is uncertain, i.e. for \(\beta < 1\), the first fraction is strictly non-negative. The term in brackets is non-negative for

\[
\frac{\gamma}{2} x^2 \leq (\nu - c)^2 \frac{\sigma (\sigma + 1)^2 + 12}{(5 - \sigma)^2(\sigma + 1)^2}
\]

Note that for homogeneous goods, i.e. \(\sigma = 1\), the second expression on the right-hand side is minimized and equals \(\frac{1}{4}\). Hence, if the investment costs are at least less then \(\frac{1}{4}(\nu - c)^2\), the first order condition in the FD regime is greater than the first order condition in the LRIC regime. Consequently, the investment incentives are always greater if the entrant has to bear some investment costs even if the NGA fails. This also follows from the first order condition
In the LRIC regime, i.e. for \( \alpha^F = 0 \), the term in the third line becomes zero as the entrant only participates in the investment costs if the NGA is a success. Thereby, the weight of the (negative) term \( \gamma x \) increases and a lower investment level \( x \) is necessary to satisfy the first order condition. Hence, the investment incentives for the incumbent decreases further in the LRIC regime than in the FD regime if the probability of success decreases, i.e. for decreasing \( \beta \).

Let us now consider the case in which both firms decided to cooperate at the previous stage. In this case, the incumbent maximizes the joint profits of the firms under consideration of the competitive retail prices on the subsequent stage of the game. The maximization problem is given by

\[
\max_x E(\pi_{CO}^I + \pi_{CO}^E) = \beta \left((p_s^{CO} - c)q_s^{CO} + (p_f^{CO} - c)q_f^{CO}\right) + (1 - \beta) \left((p_s^{CO} - c)q_s^{CO} + (p_f^{CO} - c)q_f^{CO}\right) - \frac{\gamma}{2}x^2 \tag{17}
\]

with \( \alpha^{SCO} = \alpha^{FCO} = 0 \). The derivation of the joint profit function with respect to the investment level \( x \) is given by

\[
\frac{\partial E(\pi_{CO}^I + \pi_{CO}^E)}{\partial x} = \beta \frac{4(\nu + x - c)(1 - \sigma)}{(2 - \sigma)^2(1 + \sigma)} - \gamma x = 0 \tag{18}
\]

and solving for the optimal investment yields

\[
x_{CO} = \frac{4\beta(\nu - c)(1 - \sigma)}{\gamma(2 - \sigma)^2(1 + \sigma) - 4\beta(1 - \sigma)} \tag{19}
\]

If the firms decide to cooperate, it is only optimal not to invest if the products are perfect substitutes, i.e. for \( \sigma = 1 \), or if there is no probability of success, i.e. for \( \beta = 0 \). Otherwise, the incumbent will always invest in the NGA.

The consideration of the joint profits has a positive effect on investment compared to a case in which the incumbent only considers its own profits. Substituting \( \alpha^S = \alpha^F = 0 \) in the first order condition (15) and solving for \( x \) leads to

\[
x = \frac{2\beta(\nu - c)(1 - \sigma)}{\gamma(2 - \sigma)^2(1 + \sigma) - 2\beta(1 - \sigma)} < x_{CO}
\]

Hence, the incumbent takes the entrant’s increasing demand in the success case into account and invests more.

Even though I cannot solve the first order condition (15) analytically, the previous discussion allows us to note the following proposition:
**Proposition 2.** For $0 < \beta < 1$ and $0 \leq \sigma \leq 1$, it applies

\[
\begin{align*}
    x^{FD} &> x^L \\
    x^{CO} &> x^L \text{ for } 0 \leq \sigma < \hat{\sigma}(\beta) \text{ and } x^{CO} \leq x^L \text{ for } \hat{\sigma}(\beta) \leq \sigma \leq 1
\end{align*}
\]

**Proof.** For a proof of the first statement, see the argumentation above. For a proof of the second statement, see Appendix A.3. ■

Simulations of the optimal investment decisions $x^e$ give some more detailed insights about the NGA deployment in the different regimes. Figure 1 illustrates the relation between the investments in the three regimes for different ranges of $\sigma$ and $\beta$. The results from Proposition 2 are similar to NW’s findings. The $FD$ regime yields always higher investments as the $LRIC$ regime. This is straight forward and intuitive as the investment incentives are always higher the entrant bears part of the investment costs even if the NGA fails if the success of the NGA is uncertain, i.e. $\beta \neq 1$ and $\beta \neq 0$. A difference to NW is that cooperation might yield higher investments than $FD$ and $LRIC$ subject to product differentiation and risk independent from the fixed payment $\mu$. Note that the area for which cooperation performs better than full distribution decreases with the investment cost parameter $\gamma$. The cooperation regime yields higher investments as the $LRIC$ regime in most areas. $LRIC$ only performs better as cooperation if the products are closer substitutes and if the success of the NGA is very likely, i.e. if $\sigma$ and $\beta$ are relatively high.

![Figure 1: Relative equilibrium investments subject to $\beta$ and $\sigma$ (for $\nu = 100$, $c = 20$, and $\gamma = 5$)](image.png)
3.3 Firms’ cooperation decision

On the second stage of the game, the firms decide whether to use a given access regime or to
cooprate based on their profits in both cases. The firms’ profits are given by

\[
E(\pi_I) = \beta((p_I^{S_0} - c)q_I^{S_0} + w^{S_0}q_{E}^{S_0}) + (1 - \beta)((p_I^{F_0} - c)q_I^{F_0} + w^{F_0}q_{E}^{F_0}) - (1 - \mu)\frac{\gamma}{2}x^{g2}
\]

\[
E(\pi_E) = \beta((p_E^{S_0} - c - w^{S_0})q_{E}^{S_0}) + (1 - \beta)((p_E^{F_0} - c - w^{F_0})q_{E}^{F_0}) - \mu\frac{\gamma}{2}x^{g2}
\]

with the entrant’s share of the investment costs \(\mu = 0, \frac{1}{2}\). The case with \(\mu = 0\) is motivated
by NW’s setup and allows us to compare this setup with price competition and differentiated
retail products with their findings. A major difference to their model is that they interpret this
regime as risk-sharing and therefore as a regulatory access regime. In this setup, I assume that
cooperation between firms is on a voluntary basis and firms might not be forced to this regime
but decide whether they want to cooperate. Furthermore, I consider a positive payment from
the entrant to the incumbent, i.e. \(\mu = \frac{1}{2}\). One might interpret this as a case in which both
firms build infrastructure facility in different regions. As both firms provide services for
the same retail price, let us assume that both firms provide each other access on a bill-and-keep
basis.\(^{17}\)

As there is no closed-form solution of the investment decisions in the LRIC and the FD
regime, I simulate the profits in the different regimes. Figure 2 illustrates the profit maximizing
regimes subject to the probability of success \(\beta\) and the degree of product differentiation \(\sigma\) if
the entrant does not bear any investment costs, i.e. for \(\mu = 0\).

![Figure 2: Equilibrium profits subject to \(\beta\) and \(\sigma\) (for \(\nu = 100, c = 20, \gamma = 5, \) and \(\mu = 0\))](image)

The incumbent’s profits are always the highest in the full distribution regime. If the regulator

\(^{17}\)Note that this assumption about bill-and-keep omits the opportunity that both firms charge each other a
positive fee in order to increase their marginal costs. Hence, possibly negative effects of cooperation on
competition are excluded in this setup. For a discussion of this issue in R &D literature, see e.g. Katz
implements a \textit{LRIC} regulation, the incumbent might prefer cooperation if the retail products are close substitutes and the probability of success is sufficiently high. From the entrant’s point of view, cooperation is superior to buying access if the product differentiation is sufficiently high (region \textit{A}). Interestingly, the entrant might prefer the \textit{FD} regime to the \textit{LRIC} regime if the retail products are close substitutes (region \textit{D} and \textit{E}). At first sight, this might be contra-intuitive as the entrant has to bear a part of the investment costs even if the NGA fails. The reason for this result is as follows: In the \textit{FD} regime, the incumbent invests more and the expected positive effect of investment on the reservation utility and prices dominates the negative effect of expected higher access costs. Subject to the implemented access regime, the entrant might prefer to cooperate or to buy access. Regions \textit{B} and \textit{C} in Figure 2b, represents parameter combinations for which the entrant realizes the highest profits in the \textit{LRIC} regime. If the regulator implements a \textit{FD} regime, the entrant would prefer to cooperate (region \textit{B}). In region \textit{E}, the entrant will agree to cooperation if a \textit{LRIC} regime is implemented.

Let us now consider a cooperation setup in which the entrant bears half of the investment costs, i.e. $\mu = \frac{1}{2}$. Figure 3 illustrates the regimes in which the firms maximize their profits subject to the success probability $\beta$ and the product differentiation parameter $\sigma$.

![Diagram](image)

(a) Incumbent’s profits  
(b) Entrant’s profits

Figure 3: Equilibrium profits subject to $\beta$ and $\sigma$ (for $\nu = 100$, $c = 20$, $\gamma = 5$, and $\mu = \frac{1}{2}$)

Figure 3a shows that the incumbent prefers cooperation in this setup if the products are highly differentiated (region \textit{A}). Otherwise, the \textit{FD} regime still yields the highest profits (regions \textit{B} and \textit{C}). Region \textit{C} represents the parameter combinations for which the incumbent would prefer cooperation to \textit{LRIC}. Even though competition becomes fiercer in a cooperation, the increasing investments make cooperation more attractive than \textit{LRIC}. The different relations of the entrant’s profits subject to the probability of success and the product differentiation are illustrated in Figure 3b. Cooperation yields the highest profits only for a small range of parameter combinations with nearly independent goods and high risk represented (region \textit{A}). This result is based on the entrant’s higher total costs due to the fixed payment. \textit{LRIC} becomes relatively more attractive, especially if the product differentiation increases. If the investment
is risky, the entrant might agree to cooperate if the regulator implements a \textit{LRIC} access regime but will deny to cooperate with a \textit{FD} regime. Given both figures, it becomes obvious that both firms will cooperate if investment is sufficiently risky and if the outside option is a \textit{LRIC} access regime.

To summarize, in \textit{NW}’s setup without a side payment of the entrant, i.e. for $\mu = 0$, firms will never agree to cooperate as the incumbent and the entrant have opposing incentives. The incumbent will always prefer \textit{FD} over cooperation. Given a \textit{LRIC} regulation, the incumbent would agree to cooperate in region in which the entrant prefers to buy access and in regions in which the entrant would agree to cooperate, the incumbent prefers to sell access. If we include a risk participation of the entrant, i.e. for $\mu = \frac{1}{2}$ and a positive side payment, the firms’ cooperation decisions change significantly and the firms might agree to cooperate. Both firms might prefer cooperation over a \textit{FD} regime if the retail products are almost independent.

For non-independent goods, the firms will only chose cooperation if the regulator realizes a \textit{LRIC} regulation and if the investment is risky. Hence, the outside option plays a crucial role regarding the firms’ decision between cooperation and buying and selling access in most cases.

### 3.4 Optimal regulatory policy

Given the results from the subsequent stages, it is ambiguous which regimes yield the highest welfare and consumer surplus. While the \textit{FD} regime yields the highest investment for most parameter ranges, cooperation yields the highest competition intensity on the pricing stage, i.e. the lowest prices for a given investment level $x$. The \textit{LRIC} regime performs moderately regarding the investment incentives and the competition intensity but is a precondition that both firms are willing to cooperate.

In this first stage of the game, the regulator has to decide which access regime to implement and whether to allow cooperation between firms. As a first step, let us assume that the regulator only considers the consumer surplus and weights the producer surplus with zero. The consumer surplus is derived from the utility function (1), i.e.

\[
CS^{\ell e} = \frac{(\nu + \psi x^e - p_I^{\ell e})^2 + (\nu + \psi x^e - p_E^{\ell e})^2 - 2\sigma(\nu + \psi x^e - p_I^{\ell e})(\nu + \psi x^e - p_E^{\ell e})}{2(1 - \sigma^2)}
\]

We derive the expected consumer surplus subject to the investment, to the regulatory regime, and to the success of the NGA by substituting the equilibrium prices from the pricing stage.
and by rearranging,

\[
E(CS^{\ell\varrho}) = \beta \frac{\left(\nu + x^e - c + \sqrt{(\nu + x^e - c)^2 - \frac{1}{2} \alpha e \gamma x^e v(2 - \sigma)(1 + \sigma)^2}\right)^2}{4(2 - \sigma)^2(1 + \sigma)} + (1 - \beta) \frac{\left(\nu - c + \sqrt{(\nu - c)^2 - \frac{1}{2} \alpha e \gamma x^e v(2 - \sigma)(1 + \sigma)^2}\right)^2}{4(2 - \sigma)^2(1 + \sigma)}
\] (20)

Equation (20) reveals two aspects immediately. First, the expected consumer surplus is decreasing with the product differentiation because competition is fostered and prices decrease if the products are closer substitutes. Hence, the positive effect of fiercer retail competition dominates the negative effect on investment incentives. Second, the expected consumer surplus is increasing with the probability that the NGA succeed. A higher probability of success increases the investment incentives and the negative effect of increasing prices is dominated by the increasing reservation utility.

As the first order conditions in the \textit{LRIC} and \textit{FD} regimes, i.e. equation (15), does not provide closed-form solutions, I simulate the consumer surplus in the different regimes to obtain further insights.

Figure 4: Relation of the expected consumer surplus in equilibrium subject to $\beta$ and $\sigma$

(for $\nu = 100$, $c = 20$, and $\gamma = 5$)

Figure 4 illustrates the different parameter combinations for which the different regimes yield the highest consumer surplus. In the area on the lower left side (regions A and B), cooperation yields the highest consumer surplus, in the the area on the upper side (region C), the \textit{LRIC} regime yields the highest consumer surplus, and in the area on the lower right side (regions D and E), the \textit{FD} regime yields the highest welfare. In opposite to NW’s findings, there is no single regime which yields always the highest consumer surplus.

The first insight regarding the cooperation decision is that there seems to be no need to
restrict it if the entrant bears half of the investment costs. The private incentives to cooperate might coincide with the social desirable outcome. For some parameter, e.g. $\sigma < \frac{1}{2}$ and $\beta < \frac{1}{2}$, and participation of the entrant in the investment costs, the firms might prefer to chose the consumer surplus maximizing regime. Thereby, the As the incumbent will always prefer the $FD$ regime to cooperation as long as the entrant does not bear half of the investment costs, the regulator’s decision about the access regime might distort the cooperation decision of the firms. The implementation of the $LRIC$ access regime might be a good choice in order to foster cooperation between the firms, especially if retail products are highly differentiated.

The optimal regulatory policy is in particular subject to the degree of product differentiation in the retail market. On the one hand, if we only consider telecommunications firms, i.e. firms with relatively homogeneous goods, the full distribution regime seems best. The symmetric risk allocation between both firms yield higher investment incentives. As competition is very intensive in this case, the negative effect of higher access costs on retail prices is less important and dominated by the higher investment incentives. On the other hand, we might consider firms from different markets or industries. As an example, one might think about a power supplier who asks for access in order to implement services related to smart grids. In this case, the $LRIC$ regime seems to be the best choice as the cooperation decision of the firms is not distorted and both firms might agree to cooperate. Hence, the consumer surplus maximizing outcome might be realized based on the firms’ private profit maximization incentive. The positive effect on competition due to the lower access costs, i.e. an access fee of 0, dominates the decreasing investment incentives in comparison with the $FD$ regime. From the regulator’s perspective, cooperation is even desirable in parameter ranges, especially for heterogeneous goods, for which the firms will not agree to jointly build the infrastructure. Hence, one might ask how cooperations might be fostered in this cases.

Another insight of the simulation of the expected consumer surplus is that high investments does not necessarily coincide with a high consumer surplus. Comparing Figure 1 and Figure 4 reveals that the investment incentives and consumer surplus may fall apart. Even though the $FD$ regime yield the highest investments for most parameter ranges, the higher prices and less intensive competition might dominate the positive investment incentive with symmetric risk allocation. Hence, policy should probably not only focus on coverage objectives but also consider the effects on competition.

4 Conclusion

In this paper, I discussed the effects of two different regulatory regimes, one with symmetric and one with asymmetric risk allocation, on competition and investment incentives in NGA compared to a joint roll-out by adjusting the model from Nitsche & Wiethaus (2010). First, I
implemented price competition with horizontal product differentiation. Second, I interpreted NW’s risk-sharing regime as cooperation between firms and analyzed explicitly whether and under which conditions firms might agree to jointly build the infrastructure.

The analysis reveals three main aspects: First, the objective to foster investment and to achieve specified coverage goals might lead to situations in which the positive effect of increasing investment incentives is dominated by the negative effect on competition. High investments do not necessarily coincide with a high consumer surplus. The reason is that regimes which encourage investments via symmetric risk allocation imply higher access costs for all firms and consequently higher prices for the retail products even if the new infrastructure fails. The positive investment incentives of such a regime are then dominated by the negative price effect of investment and the threat of overinvestment arises. The consumer surplus increases due to increasing investments and decreases due to increasing prices and the net effect becomes negative. This is especially the case if retail products are highly differentiated and the probability of a success of the NGA is low. Hence, the coverage goals discussed and predetermined by policy might yield an inferior market outcome from consumers’ perspective if the focus is on the extent of NGA roll-out only.

Second, the private incentives to cooperate might coincide with the socially desirable market outcome if the regulator sets the right incentives. Therefore, the implementation of restriction on cooperation seems unnecessary if we assume that competition authority ensures competition on the retail markets. A crucial aspect in order to derive benefit from the private cooperation incentives is the provided outside option, i.e. the realized access regime. Subject to the implemented access regime, the private incentives to cooperate might be distorted such that the firms will not chose the consumer surplus maximizing regime. My findings show that cooperation is superior to regulated access especially if firms provide differentiated goods. As a consequence, the focus of regulatory authorities and policy should be on actions to foster and to support cooperation between different infrastructure industries. As the incentives to cooperate might differ between investing and access seeking firms, it seems reasonable to discuss additional instruments either to increase the willingness to cooperate, e.g. subsidization, or to create “soft pressure” on firms.

Third, the optimal regulatory regime is subject to the probability of success of the new infrastructure and, possibly more important, to the degree of product differentiation. As discussed, the implemented access regime might distort the cooperation incentives of firms and therefore regulatory authorities should probably consider the type of firms seeking access to the new infrastructure. Subject to the degree of product differentiation, it might be favorable to provide different access regimes for firms from other industries, e.g. for electricity suppliers who need access to telecommunication infrastructures in order to operate smart grids.


A Appendix

A.1 Proof: For homogeneous goods, prices equal marginal costs

For homogeneous products, i.e. for $\sigma = 1$, equilibrium prices are given by

$$p^*_i = \frac{1}{2} \left( \nu + \psi x + c - \sqrt{(\nu + \psi x - c)^2 - 2\alpha e \gamma x^2} \right).$$

The access fee $w^{\ell e}$ in equilibrium equals

$$w^{\ell e} = \frac{\alpha e \gamma x^2 (2 - \sigma)(1 + \sigma)}{2(\nu + \psi x - c) + \sqrt{4(\nu + \psi x - c)^2 - 2\alpha e \gamma x^2 (2 - \sigma)(1 + \sigma)^2}}$$

The firms marginal costs in the case of homogeneous goods are

$$MC = w^{\ell e} + c = \frac{\alpha e \gamma x^2}{\nu + \psi x - c + \sqrt{(\nu + \psi x - c)^2 - 2\alpha e \gamma x^2}} + c$$

and subtracting yields

$$p^*_i - MC = 0$$

■

A.2 Proof of Proposition 1

The equilibrium prices are given by

$$p^{\ell e}_i = \frac{(c + (3 - 2\sigma)(\nu + \psi x)) - \sqrt{(\nu + \psi x - c)^2 - \frac{1}{2} \alpha e \gamma x^2 (2 - \sigma)(\sigma + 1)^2}}{2(2 - \sigma)}$$

and expected prices by

$$E(p^e_i) = \beta p^{S e}_i + (1 - \beta)p^{F e}_i$$

with $\rho = L, FD, CO$ and $i = I, E$. 
Subtracting the expected prices in the different cases for a given investment level $x > 0$ yields

$$E(p^F_i) - E(p^L_i) = (1 - \beta) \left( \frac{\sqrt{(\nu - c)^2 - (\nu + c)^2 - \frac{1}{2} \gamma x^2 (2 - \sigma)(1 + \sigma)^2}}{2(2 - \sigma)} \right)$$

$$E(p^L_i) - E(p^{CO}_i) = \frac{\beta \left( \sqrt{(\nu + x - c)^2 - (\nu + x - c)^2 - \frac{1}{2} \gamma x^2 (2 - \sigma)(1 + \sigma)^2} \right)}{2(2 - \sigma)}$$

For $0 < \beta < 1$, both expressions are strictly positive and consequently $E(p^F_i) > E(p^L_i) > E(p^{CO}_i)$ applies. For a given investment level $x$, the expected quantities decrease with the expected prices and consequently $E(Q^{CO}) > E(Q^L_x) > E(Q^F_x)$ applies.

### A.3 Proof of Proposition 2

$x^{CO} > x^L$ for $0 \leq \sigma < \tilde{\sigma}$ and $x^{CO} \leq x^L$ for $\tilde{\sigma} \leq \sigma \leq 1$

The first order conditions in the LRIC regime and with cooperation for independent goods, i.e. for $\sigma = 0$, are given by

$$\left. \frac{\partial E(p^L_i)}{\partial x} \right|_{\sigma=0} = \frac{\beta (\nu + x - c)}{4} \left( 1 + \frac{\nu + x - c}{\sqrt{(\nu + x - c)^2 - \gamma x^2}} \right)$$

$$- \gamma x \left( 1 - \frac{\beta}{8} \left( 5 - \frac{\nu + 2x - c}{\sqrt{(\nu + x - c)^2 - \gamma x^2}} \right) \right)$$

and

$$\left. \frac{\partial E(p^{CO}_i + p^{CO}_E)}{\partial x} \right|_{\sigma=0} = \beta (\nu + x - c) - \gamma x.$$

The optimal investment with cooperation and independent goods, i.e. for $\sigma = 0$, is therefore

$$x^{CO}|_{\sigma=0} = \beta \frac{\nu - c}{\gamma - \beta}.$$

Substituting the optimal investment in the case of cooperation in this first order condition and rearranging yields

$$- \frac{\beta (\nu - c)}{8(\gamma - \beta)} \left( \frac{\sqrt{\gamma (\beta^2 - \gamma (2 - \beta))}}{\sqrt{\gamma - \beta^2}} + \gamma (6 - 5 \beta) \right) < 0$$

As this term, i.e. the first order condition with LRIC and the optimal investment level with cooperation, is strictly negative, the incumbent would chose a lower investment level in the case of LRIC compared to cooperation. Consequently, it applies $x^{CO} > x^L$ for $\sigma = 0$. 

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Now let us consider the case with perfect substitutes, i.e. $\sigma = 1$. The first order condition in both regimes are given by

$$\frac{\partial E(\pi_I^L)}{\partial x} \bigg|_{\sigma=1} = -\gamma x (1 - \beta)$$

$$\frac{\partial E(\pi_CO + \pi_CE)}{\partial x} \bigg|_{\sigma=1} = -\gamma x$$

If the retail goods are perfect substitutes, the only optimal investment in both regimes is $x^{CO} = x^L = 0$.

Now let us consider the slope of the first order conditions at the position $x = 0$, i.e.

$$\frac{\partial^2 E(\pi_I^L)}{\partial x \partial \sigma} \bigg|_{x=0} = -\frac{4\beta(\nu - c)(1 - \sigma(1 - \sigma))}{(2 - \sigma)^3(\sigma + 1)^2}$$

$$\frac{\partial^2 E(\pi_CO + \pi_CE)}{\partial x \partial \sigma} \bigg|_{x=0} = -\frac{8\beta(\nu - c)(1 - \sigma(1 - \sigma))}{(2 - \sigma)^3(\sigma + 1)^2}$$

Obviously the slope of the first order condition is higher in the case with cooperation for $0 < \beta$. As a consequence, if we decrease $\sigma$ marginally below 1, the investment incentive is higher in the case with LRIC and therefore $x^L > x^{CO}$ has to apply for $\sigma = 1 - \epsilon$ with $\epsilon \to 0$.

From above arguments follows that the investment is higher in the LRIC regime if the goods are close substitutes and higher with cooperation if the goods are highly differentiated. Hence, given a probability $\beta$ there exists a $\tilde{\sigma}(\beta)$ with $0 < \tilde{\sigma}(\beta) < 1$ for which both regimes yield the same investment levels and $x^{CO} > x^L$ for $0 \leq \sigma < \tilde{\sigma}(\beta)$ and $x^{CO} \leq x^L$ for $\tilde{\sigma}(\beta) \leq \sigma \leq 1$ applies.
References


