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Cooperative investment in next generation broadband networks: A review of recent practical cases and literature

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**Cooperative investment in next generation broadband networks:
A review of recent practical cases and literature**

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Abstract

Alternative telecommunications operators have continuously invested in their own infrastructure in recent years. After more than a decade since liberalization, competitive conditions have substantially changed, especially in urban areas. European regulatory authorities have acknowledged this development by starting regional deregulation. Additionally, different forms of cooperative investments in next generation broadband have appeared on the market. The effects of such schemes on competition, investment and welfare crucially depend on the fine details of implementation. For instance, in the case of joint ventures, it matters how investment costs are shared and how internal and external access prices are determined. In the case of long-term access agreements, it is essential to consider how access tariffs are structured, whether they can adapt to market developments ex-post and whether contracts are signed before or after the investment takes place. Generally, many of these agreements allow some extent of risk sharing, offering the possibility to increase investment incentives when firms are not risk neutral. This article reviews the theoretical and empirical literature on co-investments in next generation broadband networks as well as practical cases. It is suggested that regulators consider introducing regulated co-investment agreements complementing current regulation or in some cases even substituting for it.

Keywords: next generation access, co-investment models, cooperative investment, investment sharing, investment cooperation

Cooperative investment in next generation broadband networks:

A review of recent practical cases and literature

The continuous investment of alternative operators in telecommunications infrastructure in the years after liberalization has led to increasingly differing competitive conditions across geographic areas. This is particularly the case in those network segments where alternative operators have invested; in national and regional backbone segments and also increasingly in local access directly connecting households in urban areas with next generation broadband. The latter investment may be seen as particularly valuable as high-speed broadband has substantial positive spill-overs for the whole economy. Bourreau, Cambini and Hoernig (2012a) review relevant literature and estimates.

In addition, firms as well as regulators seem to start to understand that network duplication, which traditional infrastructure competition has sometimes implied, is inefficient from a welfare point of view as investment costs are also duplicated. A natural solution is the use of cooperative investments, whereby an infrastructure able to host several partners is rolled-out. Such co-investment schemes may also be used to distribute and share investment risk between the partners implying higher investment incentives, leading to higher quality broadband and more innovation. The presence of such co-investment agreements increases, however, the complexity of the assessment of competition and investment incentives substantially, as the details of such agreements matter. In particular, allowing some co-investment clauses may be welfare optimal, while others may restrict competition too strongly (e.g. a high internal or external access price). Chapter 3 reviews the literature on cooperative investment in next generation broadband, considering the fine details of these mechanisms, as well as possible regulatory options such as the introduction of regulated joint ventures in which the firm rolling out must offer the entrant the option to join it in a joint venture at equal conditions. The development of the literature on these topics is still a work in progress, as the introduction of regional regulation took place only around 2008 and large scale broadband co-investment agreements began only around 2009 – less than half a decade before this paper was written. Given the complexity of such agreements, many questions still remain open.

Co-investments take place in a context of migration from legacy to next generation access (NGA) networks. It is useful to analyse this context in this introduction as it affects all subsequent analysis.

Traditional copper networks will be only progressively substituted by next generation infrastructure, and the regulation of both legacy and next generation infrastructure may affect this process and, in particular, investment incentives. Bourreau et al. (2012a) review the literature on migration. Most importantly, Bourreau, Cambini and Doğan (2012) find that regulated legacy access charges may affect investment in NGA in different ways. While an increase in the regulated access price to the new network in all cases increases investments, the effects of access prices associated with the legacy network are less clear. The authors show that with a high legacy network access charge

- the entrants' opportunity cost of investment is low, increasing its investment incentives (replacement effect);
- the incumbent risks to lose important wholesale profits from an investment (wholesale revenue effect)¹; and
- pressure on retail prices for legacy network based services is low. When the access price is low instead, as long as next generation services are seen as substitutes, the overall profitability of the investment is reduced (business migration effect).

Overall, it is therefore unclear whether a relatively high legacy network access charge can increase investments in next generation broadband or not. A high legacy access charge increases investment incentives of the entrant and sometimes those of the incumbent, potentially increasing dynamic efficiency, while negatively affecting static efficiency. The welfare maximising access prices a regulator should set in case of regulation of the legacy network are then shown to depend on the market environment and in particular on the amount of investment spill-overs (with high spill-overs the regulator would set a high access charge to counterbalance the negative effect it

¹ it is also assumed that an entrant can more easily roll-out its own network infrastructure once the incumbent has deployed it (investment spill-over).

has on investments of the incumbent). Finally, when setting both copper and fibre access prices, these effects interact. Whenever a legacy network is present in the models reviewed, such migration issues are considered in some way. Most papers that will be analysed in this survey assume, however, given regulated marginal cost access to the copper network for all operators, implying absence of rent from this infrastructure, minimizing distortions.

Chapter 3 describes different types of co-investment agreements for the roll-out of next generation broadband networks in Europe and as well as related regulatory principles and practice. In addition, theoretical and empirical literature on the subject is reviewed. Chapter 4 concludes discussing the major issues raised in the paper and open questions.

3. Co-investment models for next generation broadband networks

The roll-out of next generation broadband access networks implies the largest investments in telecommunications since the beginning of the 20th century, when the copper telephone access networks were deployed by the state. In the preceding chapter operators were assumed to fully duplicate infrastructure when they would roll-out a second next generation access network. This is, however, not always necessary as operators can also invest jointly and share investment cost. This chapter will review joint roll-out possibilities and risk sharing agreements in general. In this introductory section, the investment requirements are described and put into perspective.

Elixmann, Ilic, Neumann and Plückebaum (2008) show that single fibre² deployment costs are as high as 2'100€ per home connected (Table 1) in an urban cluster in Germany. There are, however, countries with substantially lower deployment costs in such areas such as Italy (1'160€). There are different reasons for this, as differing construction costs across countries, differing existing duct and aerial cabling capacities and corresponding access conditions³ as well as network topology. In addition, investment costs for in-house cabling are supposed to be higher

² FTTH (point-to-point)

³ In France for example it is assumed that operators may use existing infrastructure (sewer systems) to a large extent, reducing capital expenditure significantly. The case in Italy is similar, where ducts covering about 8% of the population, used by Telecom Italia to deploy a CATV network between 1995 and 1997 (Socrate project) were opened to competition by the Italian Antitrust authority in 2001. The free duct capacity was in the past mainly used by Fastweb. In the case of Switzerland, the model assumes that the incumbent's overall digging costs are reduced by 20% by the possibility of using existing ducts. In practice it should be noted that a utility may save even a larger part of these costs as in many cases proprietary duct networks have sufficient space left for a roll-out of an own FTTH network.

in northern than in southern countries. Investment comparisons per home passed follow a similar pattern. Homes connected consider in addition costs that are incurred to activate a customer's connection which include in-house cabling, customer premises equipment and trunk cards⁴. For homes connected the investment is then distributed on an expected target market, i.e. 50% of the potential customer base⁵ while for passed homes it is by definition distributed on 100%.

Consequently, investment cost per home connected is higher than twice the investment cost per home passed. Overall, even in a small and dense country such as Switzerland full national coverage with a single fibre FTTH network would require investments as large as €14,3bn (connected homes)⁶. With 4.5m homes, this would correspond to a national average investment cost per home connected of around 3'200€⁷. These high costs are again driven by the fact that connections become exponentially more expensive as population density decreases towards rural areas. Ilic, Neumann and Plückebaum (2009) show that in Switzerland in this case the last (very rural) cluster 16 requires 10 times higher investments per access line than the urban cluster 1 (around 1'320€). In the last cost cluster, then, it is shown that subsidies of around 11'000€⁸ per home connected would be required to make the investment viable.

3.1. *Regulatory principles in Europe*

Roll-out costs. In this section ways to reduce the investment costs for any type of investor (single investor or co-investment partner) are explored. In light of the monumental investment cost described a prominent question in the recent political debate in Europe was if there is anything that can be done to reduce the investments required for an next generation broadband and in particular a fibre access network roll-out for all operators. The European Commission (2013) has proposed a legislative proposal to reduce the cost of rolling out high-speed communication infrastructures in Europe. This initiative ended up the EU Directive numbered 2014/61/EU being put into force in April 2014. The Directive concentrates on civil engineering costs (i.e. digging up roads and lay down fibre) as around 80% of the deployment costs seem to be associated with it. The European authorities envisage thereby to reduce investment

⁴ In the Swiss case in-house cabling is included also in homes passed.

⁵ in Switzerland the baseline model foresees 75%, values adjusted to 50% are also reported though

⁶ 21,4 Mrd. Fr.

⁷ 4'800 Fr.

⁸ 16'411 Fr.

requirements through efficiencies by 20 to 30%. The Directive includes the following specific measures:

- i. Access to & transparency of existing physical infrastructure (Art. 3-4): Any network operator has the obligation to give access to its physical infrastructure for the deployment of high-speed broadband networks (30 Mbps and above), upon reasonable request and under fair terms and conditions, including price. In order to enable access to physical infrastructure, public sector bodies and network operators must provide on request minimum information including a contact point.
- ii. Coordination & transparency of planned civil works (Art. 5-6): Any network operator may negotiate coordination of civil works with electronic communications providers. In addition, undertakings performing civil works fully or partially financed by public means have to meet any reasonable request for coordination of civil works, provided that any additional cost is covered by the communications provider and that the request is made timely.
- iii. Permit granting (for rights-of-way) (Art. 7): All relevant information on procedures for granting permits for civil works must be available via a Single Information Point. Member States are encouraged to organise the application for permits by electronic means. In any event, unless national law specifically provides otherwise, any permit decision should be made in general within 4 months.
- iv. In-building infrastructure and access to them (Art. 8-9): All new buildings shall be equipped with physical infrastructure, such as mini-ducts, capable of hosting high-speed networks and with an access point, which can be easily accessed by the communications providers. Electronic communications providers shall also have the right to access to any existing in-building physical infrastructure.⁹

Essentially this Directive gives national regulatory authorities control over the duct market and facilitates rights of way and in-building access for the deployment of high-speed broadband networks (30 Mbps and above).

In practice, the Directive firstly requires all utility companies (such as electricity, gas, water, sewage, heating and transport) to meet reasonable requests by telecommunications

⁹ See Digital Agenda for Europe <http://ec.europa.eu/digital-agenda/en/news/factsheets-directive-201461ce-broadband-cost-reduction>.

operators for access to their physical infrastructure in order to deploy high-speed networks. In the event that there are no legitimate reasons to reject the request (e.g. availability of space, security, interferences), the access-seeking operator may request access at fair and non-discriminatory terms, that is at conditions and charges to be set if necessary by the regulator. Moreover, when performing civil works, companies which are partly or fully publicly financed are required to meet reasonable requests from telecommunications operators for coordination of and participation in civil works.

In order for the access to the existing physical infrastructure be effective, a set of transparency rules is laid down regarding these facilities. The minimum information which operators of such physical network infrastructures must provide to a single point of contact operated by the regulatory authority include

- the location, routes and geo-coordinates of the infrastructure;
- the size, type and current use of the infrastructure; and
- the name of the owner of the infrastructure and a final contact point.

Secondly, the Directive 2014/61/EU brings another requirement for the network operators to ensure coordination of civil works with electronic communications providers. A negotiation obligation is imposed on network owners which is translated into a coordination requirement in case the planned civil works are fully or partially financed by public means. In this second case, the leading undertaking (network operator) has to meet any reasonable request for coordination of civil works, provided that any additional cost is covered by the communications provider.

Thirdly, according to the Directive applications for permits for civil engineering works for telecommunications operators will be made over a coordinating single point of contact electronic platform operated by the regulator. Moreover, competent (e.g. local) authorities are requested to answer any request within 4 months.

Fourthly, all newly-constructed buildings and buildings undergoing major renovation are required to be equipped with high-speed broadband-ready in-building physical infrastructure. While it is unclear which technologies are included in this definition, it seems reasonable to think that traditional copper in-house wiring is excluded.

It can be expected that in many countries where such measures have not yet been applied, additional investments might be required to use alternative duct infrastructures. As in many cases, entities operating duct infrastructures (other than telecommunications operators) are publicly controlled – often by local authorities - and not necessarily operating in a profit maximizing environment, an access obligation can be reasonable in order to ensure potential entry in the broadband market via alternative physical network infrastructure (in particular ducts). In addition, the Directive aims at increasing transparency and reducing bureaucratic costs. However, even if the potential investment cost reductions envisaged by the Directive become fully realised and single, duplicate and co-invested coverage increases, the required investments in fibre will nevertheless remain very high and profitable full coverage unfeasible.

Co-investments. While the Directive 2014/61/EU addresses generic possibilities to reduce deployment costs, cooperative investment may reduce investment cost further in case of a roll-out of more than one operator in an area. The most typical case would occur in areas where two operators decide to roll-out fully in parallel (i.e. in separate duct systems). With a joint roll-out and mutual access agreements the total investment incurred may be reduced substantially. Such a co-investment agreement will be shown to not necessarily imply less flexibility for the operators or reduce competition.

Next generation broadband investment cooperations in Europe have been discussed by the NGA recommendation of the European Commission (European Commission, 2010a) which states that “*co-investments and risk-sharing mechanisms should be promoted*”. Such schemes are also analysed in BEREC (2012a)¹⁰. It is shown that to date there are few practical examples of co-investments in Europe and even less examples of interventions by regulatory or competition authorities on the conditions of such agreements. Cooperations have been registered only in France, the Netherlands, Portugal and Switzerland and they only account for a small portion of total fibre to the home deployments in Europe. BEREC (2012a) describes also that next generation broadband investment cooperations usually foresee two components. On one side the mutual access terms and on the other obligations regarding the roll-out, for instance which part of the network an operator is required to construct and give access to to the other operator. In some cases such agreements are purely financial, where one of the partners does not need to roll-out

¹⁰ A detail review can be found in annex 2

infrastructure or give access to existing or future infrastructure at all. In case of joint ventures, which is the strongest form of cooperation, investment costs and profits are shared under some rule and the new entity acts independently as one single firm.

Both the European Commission (in an earlier draft version of the NGA recommendation¹¹) and BEREC are concerned with possible limiting effects of such cooperations on competition. BEREC (2012a) notes that *“whether a market with more than two operators (e.g. three or four) may be compatible with competition depends however on numerous factors and in particular on the level of independence that these operators enjoy, especially within a co-investment agreement. While such a situation has to be assessed in detail in a market analysis or while national authorities may adapt more specific guidelines in this respect it may be said in general that if sufficient independence between the operators is ensured, a market with more than two, i.e. three or more, operators may under optimal circumstances raise low concerns about collusion and the competitive situation”*.

Of the different sharing regimes considered the BEREC report assumes that the sale of long term infeasible rights of use (IRUs) on single fibres cables in a multiple fibre (multifibre) access network may by a competitor be regarded as largely equivalent to controlling a fully independent own fibre access network¹². Similarly to the case where infrastructure is fully duplicated, it is therefore possible that co-investments lead to sufficient competition in the market for wholesale (physical) network infrastructure access to justify full deregulation (copper as well as fibre). Overall, it can be assumed that co-investment schemes may lower duplication costs and increase duopoly coverage, while having potentially some negative effects when compared to traditional duplication.

¹¹ The European Commission stated in annex III of the second draft of the NGA recommendation that in order to create sufficient upstream competition co-investment agreements need to be i) based on multifibre, ii) partners should have strictly cost-oriented access, iii) they must effectively compete downstream and iv) sufficient duct capacity must be installed. Also, a sufficient number of access providers would be necessary (three or four). This draft is no longer available on the European Commission homepage.

¹² This view is shared by the European Commission in the NGA recommendation where it is stated that *“multiple fibre lines allow alternative operators each to fully control their own connection up to the end-user. In addition access seekers can obtain full control over fibre lines, without risking discriminatory treatment in case of mandated single fibre unbundling.”*

Multifibre deployment. Ilic et al. (2009) estimate costs as well as potential network coverage under different scenarios. Compared to a single fibre network they explain multifibre networks and relevant cost drivers as follows:

- In-house wiring: The higher number of fibres implies the deployment of larger cables (depending on the number of fibres per home, for example four¹³) and more splicing work at the building entry point.
- Drop cable deployment: In the drop segment of the access network (i.e. between the distribution and the building entry point) larger cables have to be deployed. Ducts, however, are dimensioned in the model such that they could hold cables both in case of single and multifibre deployment and there are no additional construction costs involved.
- Distribution point: Contrary to the single fibre case a distribution point where operators have the possibility to connect the drop fibre lines has to be installed and every participating operator has to conduct splicing work.
- MPoP: In case of hand-over at the more distant local metropolitan point of presence level (MPoP) instead of the distribution point level, the network operating partner has to install additional feeder capacity and splice all fibres at the distribution point. This may imply constructing larger feeder ducts. At the MPoP the fibres also have to be connected to the respective optical distribution frames.

The additional costs for an operator to deploy a multifibre network therefore depend on where the access point (splice closure) for alternative operators is installed. When compared to a single fibre network in the Swiss market, Ilic et al. (2009) estimate the additional investment necessary for a multifibre network (before any interconnection of alternative operators) at around 12% (cluster 1) decreasing to around 2% (cluster 16) for hand-over at distribution point level (multifibre up to the distribution point). In case of hand-over at MPoP level (multifibre up to the MPoP) the additional investments required with respect to a simple single fibre access network

¹³ standard in Switzerland

would be of 26% (cluster 1) and 12% (cluster 16). When considering the first six clusters (those mainly concerned by the current roll-out), a multifibre roll-out would imply around 9% higher investments in case of distribution point hand-over and 18% higher investments in case of MPoP hand-over. Intuitively, in rural areas the investment share of the drop segment increases (longer lines). As in the drop segment no additional investments for cables in case of multifibre are assumed to be necessary, the relative additional investment for multifibre decreases towards rural areas.

What has to be considered additionally, however, is that once an operator is granted access to the multifibre network, it also has to invest in order to connect to the multifibre network. In case of distribution point hand-over, for instance, the alternative operator would need to duplicate investments in backhaul to reach the distribution point. Additional estimated costs by Ilic et al. (2009) are representing this, meaning that for a four fibre network and distribution point hand-over, total investment requirements increase with the number of cooperation partners connecting to the network. For instance, in the first six clusters with distribution point handover the *total* investment requirement for a multifibre network increases by 21% (from 4'124 Fr. to 4'996 Fr.) when considering connection by one cooperation partner (instead of none). The MPoP solution can therefore be socially optimal in cases when multifibre backhaul is more efficient than duplicate network backhaul. In fact, in the Swiss case, several cooperation partners agreed on hand-over at MPoP level. The cost estimates of Ilic et al. (2009) are broadly in line with other estimates such as Polynomics (2009) which estimated additional costs of 10% for multifibre networks and of the Swiss incumbent Swisscom estimating additional costs of 10 to 30%, depending on the case considered. A possible national multifibre obligation as discussed in Switzerland might, however, raise costs also in monopoly areas, reducing total coverage. The described additional costs for multifibre to society need to be traded off against its benefits.

The European Commission acknowledges the potential of multifibre in its NGA Recommendation (European Commission, 2010a) stating that multifibre has several advantages and may be conducive to long term sustainable competition. In particular, it is stated that multifibre networks

- can be deployed at a marginally higher cost than single fibre networks, and

- ensure that access seekers can obtain full control over fibre lines up to the end-user, without risking discriminatory treatment in case of mandated single fibre unbundling.

In an earlier draft of the document it was stated in addition, that multifibre networks

- enable an end-user to subscribe simultaneously to several service providers connected at the physical layer, which could in turn help develop new applications;
- facilitate churn, since no manual cross-connection operation is needed at the concentration point (any churn request may be dealt with without any down time); and
- imply lower operating costs when compared to a single fibre FTTH scenario.

The main use for the customer in urban areas is therefore that a multifibre dose is installed at the customer's home which potentially allows to choose one or more physical access providers simultaneously and easily switch between them (in Switzerland for instance four fibre connectors are installed). Cases where more than two operators could be chosen simultaneously seem to date, however, rare.

Coverage. Ilic et al. (2009) in their cost model of the Swiss market assume a fixed average revenue per user of 57€ per month independently of the service purchased (single, double, triple play)¹⁴ and independently of the number of entrants. It is then estimated that traditional fibre infrastructure competition, that is investment in two independent parallel networks, would be profitable in this case for up to 16% of households. Using multifibre co-investments it is estimated that this coverage can be increased to up to 54% of households¹⁵. Surprisingly, even four operators would be economically viable under these assumptions for 36% of households¹⁶. These results are, however, assuming certainty of (symmetric) market shares after investment. As such certainty is not given in practice the actual coverages may be significantly lower. Finally, (maximum) total coverage under these demand assumptions is given

¹⁴ Assuming 35 CHF for single play (telephony), 65 CHF for double play (telephony and broadband), 80 CHF for triple play (telephony, broadband and IPTV) and 252 CHF for business connections and applying service shares of 15%, 16%, 51% and 9%, an average monthly ARPU per connection of 85 CHF (57€) results.

¹⁵ 43% when hand-over takes place at distribution point level instead of MPoP level

¹⁶ 16% when hand-over takes place at distribution point level instead of MPoP level

by the potential profitable coverage by a single operator roll-out (single fibre) at around 60% of households (corresponding to 8.3% of the national territory)¹⁷. In the model of Ilic et al. (2009), it is therefore predicted that - even in presence of cable - about 60% of the population could profitably be covered by an FTTH network (single fibre) and that for a very large part of these accesses (54%) a multifibre roll-out (no additional partners connected) is viable¹⁸.

3.2. *Regulatory practice*

While co-investments can lead to operators having a comparable level of independence as in the case of a fully parallel roll-out, this is not necessarily the case. BEREC (2012a) distinguishes two forms of investment cooperations. On the one hand long-term cooperation agreements are considered where no common company is founded and access agreements are made for instance on a single fibre infrastructure or also under indefeasible rights of use (IRU) on dedicated fibres in case of multifibre. On the other hand the authors consider joint ventures, where the partners take equity stakes carrying jointly the full financial risk of the investment and reselling wholesale products jointly to the shareholders as well as possible downstream outsiders.

Long term cooperation agreements. Some co-investment cases observed to date in Europe have foreseen limitations to the independence and flexibility of participating operators. The following horizontal agreements part of multifibre long-term cooperation agreements had for example been notified under objection proceedings to the Swiss competition commission¹⁹

- layer 1²⁰ exclusivities (notified in all major Swiss cities), which foresee that a partner commits not to give access at layer 1 to third parties;
- compensation mechanisms (notified in all major Swiss cities except St. Gallen), which foresee that from a certain degree of usage of the network a transfer payment between the partners is necessary;

¹⁷ In case of single operator multifibre roll-out, 54% of households (in both the MPoP and the distribution point scenario) could be passed.

¹⁸ In the WIK model multifibre cooperations and costs structures do not affect total coverage.

¹⁹ See Wettbewerbskommission (2012a) as well as BEREC (2012a) for a summary

²⁰ Layer 1 indicates access at the physical layer to the naked line without any communications equipment involved exactly as is the case with unbundling.

- investment protection clauses (or non-discrimination of the partner) (notified in all major Swiss cities), which foresee that access products cannot be offered at lower prices to third parties than to the partner; and
- information exchange clauses (notified in all major Swiss cities except St. Gallen)

The Swiss competition commission has found that all these clauses (with the exception of information exchange) could potentially restrict competition. Such a finding could still be confuted by sufficient competition in the market of wholesale physical network infrastructure access and wholesale broadband access. However, in both markets, restricted to only fibre and including both dedicated and shared fibres, significant market power was found, especially for the technical problems making it difficult for cable operators to directly enter the market for wholesale physical network infrastructure access. Indirect effects through the retail market were judged not to be sufficiently strong, given that the only operator able to offer unbundling on national level was supposed to be the incumbent. The competition commission in its decisions (Wettbewerbskommission, 2012a) was therefore unable to exclude an intervention in case the operators would agree and implement the above clauses. Most clauses have subsequently been cancelled by the operators. BEREC (2012a) show that it is essential whether the investment cost is shared upfront or whether there are subsequent usage-based charges transforming - via the legal instrument of the co-investment agreement - potentially fixed costs in marginal costs thereby manipulating competition. Such agreements are possible both in the case of long term access agreements as well as under joint ventures.

Unlike in Switzerland in France cooperation agreements are largely defined ex-ante by regulation. Consequently, there is less space for intervention of the competition authority. Essentially, the French regulation foresees that any firm wanting to roll-out FTTH in an area consults the market (via the regulatory authority) for interested firms in layer 1 co-investments²¹. If there is interest by other operators to participate in such an investment, multifibre is rolled out (at least one fibre per co-investor) and the partnering operators essentially all participate bearing

²¹ ARCEP Decision 2009-1106 of 22 December 2009

equal shares of the investment cost for the multifibre infrastructure between the home and the distribution point. In exchange, they receive a long term indefeasible right of use (IRU) which defines access agreements to one or more fibres largely equivalent to property.

Independently of whether the roll-out took place using a co-investment or not, infrastructure operators in France must then provide (ex-post) access at reasonable and non-discriminatory terms to unbundling products at the distribution point. Differently to the co-investment, such prices include a risk premium. This applies to very high density areas (i.e. communes with more than 250'000 inhabitants, where at least 20% of the houses consist of more than 12 units²²). In this area, the distribution points are set for houses with more than 12 units directly inside the building. Similar terms apply in non-dense areas²³ where, however, the distribution point is much more distant (such as to collect more than 1'000 lines). The regulatory authority therefore imposes a larger extent of shared network outside dense areas. As an example *France Telecom* and *Free* have signed an agreement in July 2011 where 5 million households should be reached outside very-high density areas by 2020. Legally, the French approach is interesting as it regulates fibre access in a symmetric way (i.e. applied to any firm on the market independently of the competitive situation).

Finally, it is to be noted that in Portugal *Optimus* and *Vodafone* both construct own independent next generation broadband networks in different cities. An agreement foresees mutual access.

Joint ventures. Structural joint ventures of multiple telecommunications operators in Europe are rare. In this case operators jointly control a company and divide investment costs and profits.

In the Netherlands a *Reggeborgh-KPN* joint venture rolls-out an fibre access network. *KPN*, *Reggefibre* and other operators then buy access to fibre unbundling products from the joint venture at regulated prices. The price caps are differentiated according to cost (capex) levels ranging from 15.52€ to 25.99€ per month in 2013 (14 different areas proposed). As described in the last chapter these prices are the result of a DCF model taking into account cost and demand over the lifetime of the investment (the regulated price sets the net present value to zero).

²² The decision states also some further conditions for definition

²³ ARCEP Decision 2010-1312 of 14 December 2010

In addition, under a proposed joint venture in Fribourg in Switzerland between *Swisscom* and *Groupe E* other horizontal agreements have been rejected by the Swiss competition commission (Wettbewerbskommission, 2012b). In this case, the agreement had foreseen that ducts would remain under the control of the respective partners and that non-discriminatory wholesale offers are made. The competition authority had, however, ruled that the agreement would not constitute an independent new unit on the market taking over relevant assets of the partners – so-called full function joint venture - and considered therefore only the horizontal agreements. The main agreements were:

- The joint venture's layer 1 access price²⁴ is fixed over the whole term of the contract (same for co-investors as also third parties) in the agreement.
- There is a minimum order quantity for layer 1 products (same for co-investors as third parties)²⁵.
- A common price for access to ducts of the two parties (which remain under their respective control) is fixed.
- Both operators could make bids to the joint venture indicating total fibre roll-out costs per area. A clause foresees that the costs taken into account by the joint venture – bid of the winning operator – are increased by a fixed agreed mark up.
- The operators commit to not compete with the joint venture at later stage
- The sale of layer 1 access products at the building entry point to third parties is restricted

²⁴ terminal segment, i.e. from the distribution point to the home.

²⁵ Small alternative operators could not provide sufficient scale and would not be served by the joint venture.

The authority has shown that all these clauses could potentially reduce effective competition in the market for wholesale (physical) network infrastructure access. Subsequently, in June 2012, the joint venture has adapted the clauses according to the decision of the authority. In order to ensure full coverage of the region, the Canton was requested to enter the capital of the joint venture. The Cantonal Government had agreed to do so. At the same time Swisscom has decided to abandon the project and the cooperation form has become similar to the other Swiss agreements.

Finally, in Italy, *Trentino NGN*, controlled by the district authority, and *Telecom Italia* have set up a joint venture whereby *Telecom Italia* would roll-out in dense areas (70%), while *Trentino NGN* would roll-out alone in the rest of the area. Mutual access is then granted.

Structurally, as will be seen, under a joint venture the partners can control the access costs of all downstream players. Under (long term) access this is not the case, as the incumbents always retain access at marginal cost.

3.3. *Review of Literature*

The essential question explored in the literature is the effect that different regulated and unregulated next generation broadband co-investment options have on investment, competition and welfare. As is the case with the applied regulatory work on the subject, theoretical and empirical literature essentially distinguish joint ventures and (long term) access agreements. The key feature of a joint venture is that the roll-out may be undertaken jointly and that the partners maximise joint profits and set a single downstream access charge for the partners (and a possibly different one for outside operators). While such agreements are generically considered to be co-investment agreements, it is not entirely clear which types of access agreements should be considered co-investments. In an access agreement, the (local) network remains under full control of an incumbent which gives access at a price possibly above marginal cost. In this an asymmetry in the market is created as the investor active on the downstream market may face only its marginal network cost upstream. It may consequently in these cases be impossible for the operators to reach efficient monopoly allocations as under a joint venture. In theory any above marginal cost access price may create additional rent (an investment contribution) for the investor supporting its investment. While many types of access options are considered by the co-investment literature, only the subset of these agreements including an ex-ante fixed investment

contribution are usually considered to be co-investments²⁶, as in this case the investment risk can be shared. This section will, nevertheless, compare all joint venture and (long-term) access options analysed in the literature.

Most of the next generation broadband co-investment literature considers (ex-ante contracted) joint ventures. One particular form of joint ventures is when *insiders* (the partners) can access the infrastructure at marginal cost (access price set by the regulator or by the partners), where the network therefore can be used freely after the investment has taken place. Typically, such a configuration would lead to intense downstream competition between the partners. Cambini and Silvestri (2013) call this *basic investment sharing*²⁷. Also, in addition to these broad categories of cooperation an intermediate case is considered. The access innovation literature considers the case where the joint venture maximises joint profits by setting a jointly optimal investment level, but where the competitor would not enjoy marginal cost access as the incumbent, paying above-marginal cost (regulated) prices.

Regarding (long term) access agreements instead, a broad range of options is considered. Essentially, access charges can be fixed (independent of quantity) or linear or nonlinear in quantity (e.g. fixed plus a usage base charge together or a usage based charge with quantity discounts). Ex-ante is considered to consist of contracts signed before the investment takes place, while ex-post contracts are signed afterwards. Fixed charges can be optional (effectively paid only when access is actually requested, which may not be the case when demand turns out to be low ex-post) or non-optional (to be paid in any case). In addition, charges can be unconditional or conditional on the market outcome and in particular the level of demand in case of uncertainty. All these access options can refer to prices on the free market as well as to regulated prices (e.g. long run incremental costs, fully distributed costs (FDC) or marginal cost). In addition to the mentioned co-investment and access options often a benchmark case is considered where no access is possible.

²⁶ This seems in line with the definition given in the NGA recommendation: *Co-investment in FTTH means an arrangement between independent providers of electronic communications services with a view to deploying FTTH networks in a joint manner, in particular in less densely populated areas. Co-investment covers different legal arrangements, but typically co-investors will build network infrastructure and share physical access to that infrastructure.*

²⁷ Usually in one way or another marginal cost is born by the partners. Be it via the joint-venture or via own marginal costs equal for both operators.

Essentially, the literature described in the following sections shows that co-investments can extend duopoly (and sometimes total) coverage but risks reducing competition. As welfare effects are correspondingly contradictory, the social desirability of a particular co-investment depends on the fine details of the agreement and the outside option to which it is compared: for instance, whether both operators have non-discriminatory access to the infrastructure built, the regulatory environment, downstream competition, uncertainty, risk aversion, the structure of the access charges and the amount of investment required. Unsurprisingly, theoretical conclusions depend crucially on the hypotheses of the models. It will be shown, however, that nevertheless conclusions and recommendations to date are largely consistent. The following sections will provide an overview of the literature based on one basic paper. Table 6 in the appendix summarizes the co-investment options considered in the literature and the main assumptions and results of the respective papers.

3.3.1. Co-investment under next generation access regulation. The most detailed analysis of co-investment to date is provided by Bourreau, Cambini and Hoernig (2013). The authors use a similar model to Bourreau et al. (2012b) considering also the co-investment agreement possibility, uncertainty²⁸ and access to outsiders once the investment has been undertaken. However, unlike the rest of the co-investment literature, the authors consider a Greenfield investment and therefore no migration effects from copper reducing the model complexity (and practical relevance) to some extent but defining a good starting point for further analysis. While most other articles consider access regulation as an alternative scenario to a co-investment scheme, this article considers the two simultaneously.

Regional incumbents can here decide on the extent of Greenfield investments in their respective home areas. They invest up to the (most costly) area where gross profits can just cover the investment cost. They then announce their plans and can decide to what extent they would like to co-invest in the home area of the other incumbent - where investment cost would be split and access granted at marginal cost. This, as the authors assume that higher internal access costs reducing competition would not be tolerated by the regulator (largely corresponding to the regulated ex-ante co-investments proposed by the French regulator). The paper also assumes that the co-investors then set jointly a local access charge to the co-invested infrastructure for the

²⁸ but assuming risk neutrality

outsiders seeking access. The paper analyses the investment incentives for both total and duplicate/co-invested coverage that a co-investment option creates in three regulatory environments: no access (benchmark), traditional regulated fibre access and the free market (in duopoly areas only).

No wholesale access. When only (regulated or commercial) co-investment options exist and no traditional wholesale access, the only way to provide next generation broadband products to the market is by having access to an own infrastructure (via single roll-out, duplication or co-investment). In the case when the competitor can somehow share investment costs and then access the technology at marginal cost, as under duplication, operators would also earn duopoly profits in the co-invested areas concerned (which are reduced compared to the profits in monopoly areas). The only difference to usual duplication is then that under co-investment the investment cost can be shared, reducing the cost for duplication and extending the duopoly coverage (which is usually lower than the monopoly coverage) when compared to the case with no access at all. Duplication would therefore be fully substituted by co-investment and the duopoly coverage correspondingly extended. In line with the rest of the literature, which will be described in the following sections, the paper concludes that usually total coverage is not affected by co-investment options. This might be case only when co-investment duopoly profits exceed monopoly profits, therefore when a joint roll-out would lead to efficiencies reducing the total investment cost or when there is a strong demand expansion effect. Reasonably the former is not the case. For instance, Schneir and Xiong (2012) show that additional investments would in reality be necessary in case of any co-investment, as infrastructure would need to be more flexible and necessitate more equipment to be able to host two partners (even when considering a relatively economic passive optical network (PON) FTTH infrastructure²⁹). Regarding the demand expansion effect, as in most other papers, differentiation is key. If goods are sufficiently differentiated the sum of gross profits of two active firms may, despite increased competition, be larger than the profit of a monopolist. When this effect is sufficiently strong to balance the likely increase in investment cost, an increase in total coverage might theoretically be possible when introducing the co-investment option (even when introducing only the possibility of duplication).

²⁹ PON allows to passively bundle the traffic of multiple fibre lines on one single backhaul line, reducing feeder costs but potentially limiting flexibility.

In addition, it is shown that when the probability of low demand increases, not only both monopoly and duopoly coverages are reduced but also the difference between the two, meaning that a co-investment scheme would also reduce coverage risk.

Wholesale access at regulated terms. When instead traditional regulated ex-post³⁰ access (uniform linear usage based fee both in monopoly and duopoly areas) is also granted and demand is high, partners would ask for access outside of co-invested areas, therefore in all areas where only single infrastructure is deployed. It is assumed that access is not asked for in case demand is low and that then profits would be the same as under no access. Here it is assumed that also downstream entrants can enter on the retail market based on access regulation (both in single as well as co-invested areas) but also only in case of high demand. In such a case it is shown that usually an increase in the access charge increases both single and co-invested coverage. With respect to the no access case regulated access undermines investment incentives (total coverage) unless the regulated access charge is high and product differentiation too. Secondly, the introduction of regulated access is an alternative to the co-investment creating an opportunity cost for co-investors reducing co-investment coverage (in the extreme case of access at marginal cost, there wouldn't be any incentive to co-invest anymore independently of the investment cost). When deciding on whether to provide regulated access (instead of no access) to co-investors the regulator therefore has to trade-off enhancing competition in single infrastructure areas with a reduction of incentives for co-investments, reducing infrastructure competition. The authors argue that a solution could be that regulated access is not provided to co-investment partners (only to downstream entrants), but this may not be feasible from a legal and practical point of view.

Voluntary access. Finally, investment incentives are also analysed under voluntary access, where in co-invested areas due to infrastructure competition access prices are fully deregulated (regional regulation) while traditional regulation remains in place in single infrastructure areas. In this case the co-investors will allow local access only when profitable, thereby weakly increasing their local profits. Co-investment coverage therefore increases with respect to both the no access as well as the regulated access scenario (while voluntary access has usually no effect on total coverage as regulation in monopoly areas remains in place).

³⁰ i.e. access is asked for after the investment is sunk and demand uncertainty has resolved

Voluntary access for co-investments is, however, not necessarily socially optimal, as it may lead to higher retail prices. The authors show that such deregulation of co-investments only provides higher welfare than no access in case services are sufficiently differentiated. Also, compared to regulated access, voluntary access only leads to higher welfare when services are highly differentiated and the compared access charge under regulation is high. The first result is obtained as the introduction of a freely and jointly profit maximising access charge by the co-investors may be used to soften downstream competition³¹. This may increase the co-investors total profits even in presence of a new entrant when compared to no access, implying, however, less welfare. In the case where, instead, goods are highly differentiated, there would be no such negative competitive effect of deregulation and welfare would be enhanced. The welfare effects of voluntary access compared to regulated access are then straightforward. Given sufficient differentiation (negative effect of co-investment on competition is weak) and a high enough access charge under regulation, local welfare in a deregulated co-investment area is higher than in a regulated single infrastructure area. Also, as has been shown, voluntary access would increase co-investment coverage. Therefore, only when differentiation is strong and the compared regulated access charges high may deregulation of co-investments be a socially better choice than traditional access regulation. The French authority seems to share this view as it has actually not only regulated co-investment access conditions but also ex-post access conditions to the infrastructure. Under the current regulatory framework, it may propose to lift this part of regulation when the co-investment grants sufficient competition.

3.3.2. Co-investment models as an alternative to regulation. While the rest of the literature does not take geographical aspects explicitly into account, different aspects of the preceding model are also analysed when considering the presence of a legacy network on a whole, possibly urban area and upgrade investments which, depending on their size and the ability of the operators to sell quality services, may unlock additional willingness to pay.

Overall, modelling approaches in the rest of the literature vary strongly. For instance, Nietzsche and Wiethaus (2011), Cambini and Silvestri (2012) and Cambini and Silvestri (2013) compare different exogenous risk-sharing agreement options (traditional joint ventures and basic

³¹ This is also described in BEREC (2012), where it is stated that compensatory mechanisms after the investment, which imply effective above marginal cost access prices, can be strategically used to reduce competition in the market.

sharing) to - alternative - traditional regulation options (e.g. LRIC, FDC, marginal cost, free market, no access). Unlike Bourreau et al. (2013) these authors consider an incumbent with an existing copper network to which all players have non-discriminatory access at marginal cost (regulated). Except for Cambini and Silvestri (2013), these papers take into account uncertainty. The rest of the literature is now reviewed, considering the following broad categories of models: Presence of uncertainty, differing ability of partners to sell next generation products and the presence of outsiders. Subsequently, the access innovation literature is analysed where access conditions between the incumbent and the co-investor may differ and the investment has no quality effect exclusively reducing access cost. Then, the literature on long term access regimes is reviewed under which the incumbent continues to fully control the network, while being able in some cases to share the investment risk to some extent. Finally, the empirical literature on co-investments is described.

3.3.2.1. Certainty. The simplest setting is provided by Cambini and Silvestri (2013) who consider a given roll-out area under certainty. Consumers' willingness to pay for next generation broadband depends on the amount of investments in quality. Moreover, the two considered possible incumbents are equally good in transforming quality investments in willingness to pay. They then rank market outcomes regarding investment, competition and welfare for the traditional joint venture case, the basic sharing case as well as the traditional regulated monopoly case. Cambini and Silvestri (2012) introduce uncertainty making similar but more detailed conclusions considering in addition the case where the next generation network is left unregulated, while the legacy network is continued to be regulated. Nietsche and Wiethaus (2011) consider a similar model under uncertainty comparing the basic sharing case to specific regulation such as LRIC or FDC.

In Cambini and Silvestri (2013), a downstream competitor has the possibility to enter a basic sharing agreement with the incumbent before the investment (ex-post access in case of agreement is granted for free for the partners, having to pay only own marginal costs for the usage of the next generation infrastructure). Duplication is therefore excluded. Investment costs as well as possible wholesale profits are as usual equally divided. Consumers are here having a demand for basic broadband which can also be offered based on the legacy network and demand for value added services based on the next generation infrastructure as in Foros (2004) and Katz

and Shapiro (1985). How much the next generation access infrastructure investment increases the consumers' willingness to pay depends on the industry's ability to transform input quality improvement into output.

Essentially, two scenarios are analysed. One where all operators are part of the co-investment agreement and one where there are outsiders asking for usage-based access ex-post. In the regulated scenario, Cambini and Silvestri (2013) assume that no type of investment-sharing option exists and that the regulator sets the welfare-maximising access price to the incumbent's infrastructure (ex-post and linear usage-based) for all access seekers. It is shown that in this case the optimal next generation access price is set at marginal cost (as for copper). The investment extent would then depend on the willingness to pay for next generation services and investment costs and it would decrease with the number of outsiders using access, as these would compete industry profits away (Cournot). In equilibrium in the basic sharing scenario, when all firms participate in it, instead, industry profits and investment incentives are increased compared to the regulatory scenario, as now also next generation broadband profits generated by the co-investing (former downstream) competitors can be taken into account when making the investment decision. In this case the whole spill-over of the investment on the competitor can be considered when deciding on investment. Typically any other form of collaboration (e.g. ex-post access, especially when regulated) would reduce the amount of rent that can be extracted from the competitor, reducing thereby investment incentives, as also shown in Inderst and Peitz (2013). Finally, in case of a traditional joint venture, when partners are also free to choose the access price to the co-invested network, competition can also be softened increasing profits and investment incentives even further.

Equilibrium output it is shown to be highest under basic sharing. Firstly, it is higher than under joint venture, where partners may set a high access price to dampen downstream competition restricting output³². Secondly, it is higher than under regulated access, even though access prices to the network are identical in equilibrium (marginal cost), as investment and therefore demand are increased under basic sharing. Finally, output under joint venture in

³² . As stakeholders will be redistributed 50% of the JVs profits the access price would only have a financial impact on an operator when its use of the infrastructure would be different than 50%/50%; this is not the case in this symmetric and certain environment. However, otherwise a JV is vehicle for internal transfers (similar to full compensation payments in the Swiss case under loose cooperation agreements).

equilibrium would usually be higher than under regulation (at least when willingness to pay for quality investments is sufficiently high and costs sufficiently low)³³.

It is also shown that the ranking with respect to total welfare in this model is identical. Increasing both investment and competition, basic sharing is superior to access regulation (similar conclusions are described in Nietzsche and Wiethaus (2011) and Cambini and Silvestri (2013)). By contrast, a joint venture with freely chosen access charges is a combination between strongest investment incentives and strongest restriction of competition. Again, when willingness to pay for quality investments is sufficiently high and costs sufficiently low it is shown to be superior to regulation as in this case investment is having more welfare value. Finally, a joint venture option is shown to always generate less welfare than basic sharing as the increase in investment incentives in this model with an exponential cost function and Cournot competition can never compensate the loss in terms of competition.

Investment sharing agreements and their effects on competition and investment capabilities under certainty are also studied by Ribeiro (2016). His paper proposes a stylised model of competition between three facility-based firms, whereby an incumbent and other licensed operator (OLO) may jointly develop fibre network infrastructure while a rival OLO develops cable network infrastructure. Differently from Cambini and Silvestri (2013), Ribeiro (2016) also compares partial integration with full integration, finding that the former may be a socially desirable regime. This conclusion is justified by the reduction of industry output and consumer surplus in addition to the ambiguous effect on producer surplus once changing from partial integration to full integration. In the model, services are sold to consumers at a fixed subscription fee independently of actual usage and time. Firms face downward sloping demand curves and capacity constraints in the regional and global backbones which implies Cournot competition in the retail market. Under partial integration, incumbent firms cooperatively chose the consortium's investment level, while a facility-based outsider (cable firm) chooses the corresponding investment level. Under full integration, all there firms cooperatively chose the consortium's investment level. Also first findings are investigated further by extending the analysis to four market operators where the fourth firm is a service-based competitor.

The findings of the study are complementary to those of Cambini and Silvestri (2013) in the sense that exclusion of the facility-based outsider does not hold whereas exclusion of the

³³ The ranking in terms of consumer welfare is identical.

service-based outsider holds in the tight oligopoly with simultaneous presence of co-investments if unregulated. Thus the competitive nature of outsiders affects exclusionary behaviour.

Accordingly the author concludes that when there is an increasing number of investment sharing agreements taking place, regulators should promote static (dynamic) efficiency if outsiders are facility-based (service-based) competitive given the low (high) risk of exclusion, respectively.

The results also reflect on the market environment described as “tight oligopoly” with simultaneous presence of basic investment sharing agreement.

According to the results NRAs should regulate the wholesale access prices under two circumstances. On the one hand, if the investment effort is excessively high, producer surplus is limited because the NGN profitability is too low meaning that regulator should provide favourable conditions to boost fibre roll-out. On the other hand if the investment effort is intermediate provided that an excessively high gap exists between the vertical spill-overs of fibre and cable, the regulator should take measures to reduce the sharp asymmetry between vertical spill-overs. Hence, ex post regulatory intervention on the fibre access price improves social welfare if the investment effort is excessively high. Moreover, ex post intervention is also justified if the investment effort is intermediate as long as consumers excessively overvalue fibre services in relation to cable services. Under these market conditions, ex post asymmetric access price intervention is found legitimate to enhance social welfare and avoid damping of market competitiveness.

3.3.2.2. Uncertainty. Nietzsche and Wiethaus (2011) and Cambini and Silvestri (2012) introduce uncertainty such that the willingness to pay is enhanced only in case of success. Conversely, in the case of failure willingness to pay is not enhanced. The binary nature of success allows to introduce the element of uncertainty without excessive complexity of the model. In Cambini and Silvestri (2012) differently to Cambini and Silvestri (2013) and Nietzsche and Wiethaus (2011) and following more closely Foros (2004) the willingness to pay for quality of consumers may vary across firms. The results found under uncertainty are not in contrast with the results found in Cambini and Silvestri (2013) under certainty.

Differing ability to increase willingness to pay of consumers across firms. In Cambini and Silvestri (2012) again an incumbent with access to a legacy infrastructure has an option to invest in next generation broadband under different possible exogenous regulatory regimes or a sharing option with a competitor. Demand is revealed only in the retail competition phase. Similarly to Cambini and Silvestri (2013) three access regimes are considered: Basic investment sharing, next generation broadband regulation, and the free market. In all cases a regulated legacy (copper) option continues to be available.

In this model the incumbent and possibly the alternative operator in case of co-investment must decide on when to invest in a given (supposedly urban) area under consideration (investment extent is supposed to be 100%). Investment costs are assumed to decrease over time meaning that the investment is becoming more profitable over time and that at some point investment would always take place. Practically, an exponential discount factor (between 0 and 1) is applied to a (quadratic) investment cost function as in Bourreau and Dogan (2005) and Riordan (1992), depending on the adoption date of the new technology. The earlier the investment takes place the higher the discount factor, and consequently, the investment costs that need to be incurred to upgrade the network³⁴. The investor will decide therefore on the investment timing, which will determine the investment costs. Until the moment of adoption the incumbent makes profits based on its legacy copper network. The next generation infrastructure generates profits only afterwards. The regulator in this model sets access prices ex-ante, but access prices can be conditional (i.e. higher in case demand turns out to be high). In this model, it is mostly assumed that the entrant has to commit to an access regime and cannot switch back to copper after demand is revealed. It therefore bears some risk as well.

Under traditional next generation access regulation it is shown that when the incumbent is much more efficient in creating willingness to pay for next generation services compared to the competitor, the regulator would set an expected welfare maximising-price excluding the competitor from the next generation infrastructure. This case is, however, assumed to be unrealistic. When the ability of the competitor increases slightly but the incumbent is still better than the competitor, the regulator would set an above marginal cost fibre access charge making its entry viable. Finally, when the ability of the competitor further increases and is only slightly

³⁴ When the investment takes place in period 0, the investment cost is not reduced at all. When taking place in period three it would be reduced substantially.

lower than the ability of the incumbent, and in case it is even higher, the regulator would set a negative access charge in case of success in order to incentivize the alternative operator to offer next generation infrastructure based products, given that only the competitor's presence may unlock (quality) competition and possibly increased willingness to pay downstream. Negative access charges are, however, excluded and it is assumed that in such cases the fibre access charge would be set at marginal cost as copper. The authors also show that a situation where the regulator cannot set conditional access prices would be suboptimal, as the alternative operator could be inefficiently forced out of the next generation broadband market in case of failure. This is the case as above marginal cost next generation access prices would be valid also in the case of failure and could imply that profits would be lower than with copper. Finally, the incumbent decides on the investment timing. The authors find that the better the competitor is on the fibre market the later the incumbent would invest (as in Foros, 2004). This occurs when the next generation access price is set at marginal cost, meaning that the investment is pure spill-over but also in the case of above marginal cost next generation access prices. Also, when the probability of success increases, the investment is undertaken earlier and the incumbent's incentives to invest decrease less strongly with the ability of the competitor.

In the case of full deregulation of next generation broadband a simple take-it-or-leave it offer is considered as opposed to Nash bargaining as considered below by Nitsche and Wiethaus (2011). Moreover, it is assumed that in case of failure, the access price would be set at marginal cost. It turns out that the incumbent would set the next generation access price in case of success such that

- when the competitor is significantly less efficient in offering value-added services, it is excluded from the market;
- when the competitor's ability increases but not up to a point where he would be significantly better than the incumbent, the incumbent will charge above marginal cost prices which just allow the alternative player to enter the next generation broadband market; and

- when the competitor is considerably better, access is granted fully extracting the willingness to pay which the incumbent is unable to generate himself (monopoly prices).

These conclusions differ from Foros (2004) where the outside option is market exit (instead of copper) and the incumbent would charge an unconstrained next generation access price excluding the entrant, whenever the competitor has a lower ability to sell next generation broadband services. Here, the cases of exclusions are reduced as to make entry of the competitor viable even if it is (to some extent) less efficient than the incumbent. This is due to the trade-off that if it would not allow the entrant on the next generation infrastructure, it would continue to compete for basic services over the legacy network at regulated marginal cost access prices, which is creating an opportunity cost for the incumbent. Granting next generation access, the incumbent can at least earn some upstream profits, which it would not earn in case the competitor would continue to use the copper network. Lifting copper regulation would therefore substantially weaken the competitor's position. Finally, in case of deregulation of next generation broadband the authors find that the better the competitor is on the fibre market the earlier the incumbent would invest, as here the incumbent can always capture part of the rent of the competitor.

Under basic investment sharing, the two firms choose the investment time to maximize their joint expected profits. In equilibrium, when at the start the competitor is better than the incumbent (or when the incumbent is better but not too much), the investment is undertaken earlier when the competitor becomes better in selling next generation broadband services. Conversely, when the incumbent is considerably better than the competitor, an increase in the competitor's ability would delay the moment of investment. Basic investment sharing therefore represents an intermediate case with respect to deregulation of next generation access and regulation as it internalises the effects of retail competition.

The authors conclude as the rest of the literature that basic sharing leads to more (or the same level of) competition and output than in case of next generation access regulation (but also than deregulation). The equilibrium in terms of time of investment depends on next generation access conditions and therefore on the firms respective abilities to sell next generation services in the retail market. The investment is undertaken earliest in case of deregulation, while the ranking between next generation regulation and basic sharing depends on the parameters. When the

regulated next generation access price is set to zero (marginal cost), the investment is undertaken later than under basic sharing as in this case investment costs can be shared. When the regulated next generation access price is positive instead, the relationship is ambiguous. Intuitively, while in case of investment the competitor may always profit from some spill-over effect, the incumbent may, in case of deregulation, also capture a part of this rent via the upstream market. In case of next generation regulation instead – if the incumbent has not a considerably higher ability to increase willingness to pay for next generation broadband - the regulator would set prices at marginal cost decreasing the incumbent's wholesale profits to zero. Investment incentives are therefore reduced and investments take place later. Finally, when the success probability increases, the investments are in all scenarios anticipated. Uncertainty is therefore a major source for suboptimal investment.

The interpretation in terms of total welfare of this model is unclear. When the competitor is better than the incumbent in providing next generation services (and a regulator would consequently set the next generation access price to zero), basic sharing is always the socially optimal choice. Even though investment incentives are lower than under deregulation basic sharing more than compensates this in with the intensity of competition. Also, deregulation is more efficient than regulation in this case. When instead the incumbent is better (but with the competitor's ability not so low as to be excluded) next generation regulation continues to yield lowest welfare, while the ranking of basic sharing and deregulation is unclear. When the ability of the competitor is further reduced, the incumbent excludes it from the next generation broadband market in case of deregulation. In this case basic sharing is better than next generation regulation from a welfare point of view, while the relationship between deregulation and basic sharing is ambiguous.

Equal ability to increase willingness to pay of consumers across firms. Nietsche and Wiethaus (2011) use a similar but simpler model than Cambini and Silvestri (2012). The factor which transforms quality investments in willingness to pay in case of success is assumed to be one for both the incumbent and the competitor. When access to the next generation infrastructure is granted, both players are therefore supposed to be equally good at selling next generation products. Again the outside option is regulated copper access. The regulatory options considered in this article are, however, detailed regulatory regimes (LRIC, FDC).

Under long run incremental cost, the access price is considered to be an average (investment) cost per unit (marginal costs such as the cost of production and distribution are again sustained in addition by both the incumbent and the competitor). It is assumed, however, that if the investment is unsuccessful and no additional willingness to pay is created by the next generation investment, the regulated next generation access price is set to zero. Therefore, only in case of success can the incumbent pass-on investment costs to the competitor under long run incremental costs here. In case of failure, the willingness to pay of consumers is not increased and the incumbent would continue to sell copper products under access conditions as before and could not recoup its next generation investment cost.

Under fully distributed cost, instead, access prices are also defined as investment cost per unit. But here the incumbent is allowed to recoup costs also in case of failure (positive regulated next generation access charge also in this case). The form in which investment costs are recouped in case of failure can be by a forced full switch to fibre for the access seeker or by continued parallel services whereby, however, copper-based products have to contribute to cover the next generation investment cost.

Finally, a basic sharing agreement is considered as well as a deregulated environment. In the case of deregulation, negotiation for access to the network in case of success is modelled differently to Cambini and Silvestri (2012). A Nash bargaining solution is assumed, meaning that rent extraction by the incumbent is more limited.

Regarding competition, the authors show that in case of success it is strongest in case of basic sharing where implicit access prices are lowest (in particular when compared to LRIC). As the equilibrium outputs in case of failure would be the same, expected output on aggregate is increased with basic sharing over long run incremental cost. Moreover, it is shown that long run incremental cost leads to higher expected output than fully distributed cost, as the outcomes in case of success are equivalent, but as the latter would increase access costs for the competitor also in case of failure, leading to lower output in this case. Finally, it is also shown that basic sharing generates more output than next generation access deregulation as deregulation leads to positive transfers in case of success.

When looking at investment, with long run incremental cost in case of success investment costs are effectively reduced by 50% as output in this setting is always symmetric. With fully distributed cost the entrant bears its investment share also in case of failure. Under basic risk

sharing instead, all investment costs are entirely sunk and do not allow any allocation of investments, as second stage marginal access costs lead to a high level of retail competition and consequently limited investment incentives. Basic sharing therefore induces less investment than both fully distributed cost and deregulation. The ranking between basic sharing and long run incremental cost is, however, not entirely clear. As under and long run incremental cost the incumbent has to share the benefits of the network in case of success, but it cannot recoup or share investment costs in case of failure, the investment incentives strongly depend on the probability of success. In case of certainty for instance and long run incremental cost would provide better investment incentives than risk sharing. In case the probability of success is low enough though (under 85%), basic sharing turns out to induce more investments as it allows to share not only benefits but also investment costs upfront.

The authors finally compare the performance of these regulatory options in terms of consumer welfare. It turns out that risk sharing is superior to and long run incremental cost both in terms of competition as in terms of investment incentives. This is, however, not always the case with respect to other regulatory options such as deregulation and fully distributed cost. In a numerical example, the authors show that usually expected consumer surplus for a large range of parameters (probability of success lower than 90%) is highest for risk sharing, followed by fully distributed cost, deregulation, and long run incremental cost. The high performance of basic sharing is due to its property of leading to a very high intensity of competition, but at the same time giving reasonable investment incentives ex-ante allowing the sharing of both benefits and costs in all cases. It should be noted that risk sharing remains optimal even if the probability of success is above 90% and in a certain environment. In this case only the ranking between deregulation and long run incremental cost becomes unclear. Interestingly, fully distributed cost dominates both deregulation as well as long run incremental cost. Apparently the higher investment incentives more than compensate lower competitive intensity. Furthermore, with some uncertainty even deregulation appears to dominate long run incremental cost (for a large set of parameters). This final result depends on the particular form of access prices under deregulation (Nash bargaining) and the hypotheses of competition.

3.3.2.3. Outsiders. The only article next to Bourreau et al. (2013) to consider ex-post outsiders in case of co-investment is Cambini and Silvestri (2013). In this case the insiders are

able to set a (usage-based) access price for outsiders, which is potentially different from the insider fee. Results are, however, not directly comparable as in Cambini and Silvestri (2013) the presence of a regulated legacy network option changes the model fundamentally. Similarly, though, the presence of an outsider undermines investment incentives, in particular in case of regulation.

In the basic sharing case, when an outsider is considered, the partners continue to access the infrastructure at marginal cost while the outsider has to pay a higher next generation network access fee. The outsider also has the alternative possibility to use the copper network at regulated marginal cost prices (same as for next generation access) or to not enter at all. Given the specified demand structure, the more the partners invest in quality, the less attractive is providing copper retail services for the outsiders. Depending on the extent of investment, the outsider may therefore even be fully excluded from the market, even though access to copper is regulated. In equilibrium the authors show that when willingness to pay for quality investments is sufficiently high and costs sufficiently low, the partners set an external access fee so high, that the entrant is excluded from the next generation network. Intuitively, when the competitive advantage from fibre over copper services is large, the temptation to exclude the entrant from the next generation infrastructure is higher for the partners, as profits in such a situation increase. It is also shown that under the same circumstances the partners choose an investment extent in the preceding stage which is high enough to exclude the entrant also from entering via copper (even though access is regulated at marginal cost), in which case the investment level is identical to the one under no access. When willingness to pay for quality investments is instead sufficiently low and costs sufficiently high, the partners set an above marginal cost access price which makes entry of the outsider viable. Intuitively, the entrant is not excluded in this case is that it is simply not fully excludable when regulated copper access is granted at marginal cost and the willingness to pay cannot be significantly enhanced at reasonable cost. Once the entrant is not excludable, access can also be granted to the next generation network, where more rent can be extracted.

In the joint venture case instead, the partners choose the internal as well as the external access fee freely. When the willingness to pay for quality investments is sufficiently high and costs sufficiently low, the partners again exclude the outsider from the next generation infrastructure via its access charge. In this case they would set their internal access charge at marginal cost in order to be able to compete at best on next generation infrastructure base with

the copper-based competitor. As before, however, in equilibrium the entrant is excluded also from copper-based entry through a sufficient investment extent when it is excluded from next generation based entry. In the inverse case, the partners would set an outsider fee above marginal cost which would make next generation infrastructure based entry for the competitor viable as well as an identical internal fee to overall soften next generation based competition. A regulatory intervention may here in both cases prevent discrimination and possibly foreclosure. A regulator would again choose marginal cost access for all operators (insiders and outsiders), in which case the equilibrium investment under joint venture would be the same as under basic sharing. French regulation is largely in line with this observation as it foresees regulated ex-post access for outsiders but includes a risk premium.

Under a joint venture the partners are again able to increase profits by reducing downstream competition. With outsiders, however, also under basic sharing some dampening of competition via the outsiders' access fee is possible. This means that for a given investment extent output is highest and investment level lowest under regulation (uniform regulation at marginal cost). Also, output under basic sharing is higher than under joint venture. The rankings compared to the no outsider case are now different as the presence of an outsider implies that the insider fee is set low by the partners. In equilibrium, Cambini and Silvestri (2013) show that with an outsider, sharing agreements increase investments incentives (even more under joint venture than under basic sharing) over regulation but dampen competition further and lead more likely to exclusion. However, the benefits are such that total welfare is always enhanced by sharing models over the regulated case. The exact ranking between basic sharing and joint venture is unclear and depends again on the willingness to pay for next generation services and investment costs. It seems therefore that notwithstanding the fact that sharing agreements can lead to a reduction of competition and potential foreclosure of outsiders, they can be socially optimal when compared to a situation with next generation access regulation at marginal cost, which would reduce industry profits with every additional outside entrant. Regulators' fears of a reduction of competition are therefore well founded when outsiders are present. Nevertheless, they should consider that regulation can reduce investment incentives to a point where social welfare is decreased.

3.3.3. *Access innovation.* Some interesting insights can be obtained from the literature on cooperative access innovation. Mizuno (2009) considers access innovation representing investments with the effect of exclusively reducing network access costs (i.e. no quality component)³⁵. While two firms compete with horizontally differentiated goods at the retail stage (Cournot), two exogenous options are considered in the investment stage. On one hand a non-cooperative regime in which the first moving incumbent alone determines the investment level, maximizing its profits, and on the other hand a cooperative access innovation regime (joint venture) whereby the investment is chosen that maximizes joint profits of the incumbent and an entrant while sharing the fixed investment cost somehow and continuing to compete downstream. Unlike all other articles considered, the access fee the competitor has to pay ex-post is different from the one the incumbent bears. It has to continue to pay a usage-based (linear) access fee which is set by the regulator.

Under uncertainty in a benchmark scenario an unconditional regulated access price is considered which does not adjust to realised costs and is fixed. In this case, the investment incentives for access innovation are higher in case of no cooperation, as the entrant does not have any spill-over from the access innovation (results are reported in Table 2). Even worse for the entrant, the access innovation will lead to increased competitiveness of the incumbent reducing its market share and profits. In a more realistic scenario where the regulator imposes a conditional cost-based access pricing rule, the access charge is a fixed multiple (usually above 1) of the realized access cost ex-post (e.g. adding common non-traffic dependent cost elements as a fixed percentage of the access cost on top). Expenditure for access innovation investment may be also included in this perspective. Under any such access rule access innovation and cost reductions by the incumbent now also have a positive spill-over effect on the entrant as a reduction of the access cost also reduces the access charge and therefore the entrant's marginal costs.

When the spill-over effect (and access charge) is very small, the entrant's access costs are reduced much less than the incumbents, leading to a strong competitive imbalance, given that the entrant's costs increase relatively to the incumbent's costs. In this case the entrant overall does not benefit from access innovation and access charge reduction and it would - in case of cooperation - work to reduce investments in innovation. A non-cooperative investment by the

³⁵ For simplicity it is assumed that the incumbent's marginal costs are equal to average costs.

incumbent would therefore lead to higher investments. When the spill-over effect instead becomes high enough, the entrant also benefits sufficiently from access innovation and cooperative investment can increase investment over non-cooperative investment. Finally, when the spill-over effect becomes very high, the entrant benefits more from the access innovation than the incumbent, whose overall benefits from access innovation may become negative due to competitive effects on the entrant. No investment would then be undertaken as the entrant is supposed to be unable to invest alone. Access charges that are too high, therefore - contrary to intuition - do here not incentivize investment in access innovation but deteriorate it. This is, however, only the case because of the particular regulated access price structure (fixed access price rule). When the access charge is not a multiple of the access cost, but instead is set as a two-part tariff, where non-traffic related costs are set separately as a fixed *set-up fee* in addition to usage-based charges, the scheme would represent a mix between a fixed committed price and a marginal access cost rule, implying that the limitation of investment incentives under the non-cooperative scheme are limited. The author suggests that regulators should therefore take care when structuring regulatory access products, as incentives for both non-cooperative and cooperative access innovation can be distorted. Regarding the cooperation scheme per se it is not always effective, but in case of a regulated (cost) conditional access charge, it allows overall to enhance investment incentives. Also, given the above, an increase in competition (goods becoming closer substitutes) reduces the range of regulated access charges (and spill-over effects) for which cooperation is viable.

In the rest of the paper the author concludes that the usage-based regulated access charge, considered the only instrument of the regulator, should be set below marginal cost in order to compensate for presumed market power at retail level, both in the non-cooperative and cooperative regime. When the access pricing rule is such that the access charge is equal to realized incremental access costs (LRIC) the level of spill-overs is shown to be large. It is then shown that such an access pricing regime would not only imply that cooperation leads to more investment incentives with respect to a non-cooperative regime, but also that under cooperation total welfare would be higher. In case of a two-part tariff, it is shown that it might lead to higher investment incentives under the non-cooperative scheme but also that it would not be welfare optimal in this context.

3.3.4. Long term access agreements.

3.3.4.1. *Certainty.* The co-investment options considered in the rest of this survey foresee usually joint profit maximisation. There are, however, also possibilities to share investment risk without joint control. This is in particular the case with long term access agreements where a competitor may reach an agreement with the incumbent foreseeing, for instance, a fixed unconditional ex-ante investment contribution in exchange for more favourable ex-post access. Inderst and Peitz (2012a) as well as Inderst, Kühling, Neumann and Peitz (2012) analyse the effects of different access options including ex-ante long term access agreements to next generation infrastructures in a certain environment. They derive critical levels of investments below which investment is undertaken under different access options. The outside option is again represented by regulated copper access at marginal cost.

Two operators are supposed to fully control a hinterland of particularly loyal customers beyond reach for the competitor and served exclusively. In addition, non-captive consumers are located on a Hotelling line with uniformly distributed customers, and products are located at the two endpoints. In such a setting it is shown that the equilibrium price difference of the two products increases with differences in consumers' gross utilities (or willingness to pay), marginal costs or the extent of hinterlands. It is, however, assumed that customers' gross utilities only differ between the firms when they use different technologies. With given fixed, price independent hinterlands - and therefore industry demand - the authors note also that the property that firms can only set a uniform price for all customers (captive and non-captive), means that firms with a larger hinterland are less aggressive in the competitive segment consequently holding a lower market share in this segment. In the cited analysis, however, symmetric hinterlands are assumed. Analogously, equilibrium conditions are derived for the case when demand in the monopoly hinterland segments is price dependent (as well as consequently industry demand). The next generation broadband investment decision takes place consisting in a 0-1 decision in a regional market (the incumbent deciding first on investment). In the following the different network access scenarios for the competitor are analysed under certainty (for a summary see Table 3).

When no access possibility for the competitors exists, duplication may occur if investment requirements are very low. In the other extreme case, investment requirements are so high that not even a single operator's investment is viable. In the intermediate case, only one of

both firms' investments is viable and only one firm invests in equilibrium. As a second option traditional ex-post access is considered. It is first assumed that access fees take the form of a linear charge per subscriber to recoup the investment and that the investor has full bargaining power.

Price independent industry demand. When industry demand is price independent, an increase in linear access prices above marginal cost is shown for the competitor to work like an increase in its marginal costs and leads to an equivalent increase in the retail price in equilibrium (see De Bijl and Peitz, 2006) as the whole marginal cost increase can be passed on one-to-one in equilibrium. The entrants profit remains therefore unchanged with changes in the level of the access charge. It is further shown that in equilibrium the same is true for the incumbents' prices via opportunity costs.

The incumbent would therefore be the only firm benefiting from this access price increase being able to extract more rent from the entrant via higher wholesale profits. Foreclosure never happens in this case as the investor is able to always increase its profits through access, extracting rent generated by the entrant (competitor's hinterland). Total coverage is therefore increased with an access possibility. Investment incentives are, however, not efficient here as the linear access charge determines jointly the level of industry profits and their distribution between the access seeker and the investor. Under this scheme the competitor's net profits from access are the profits generated in duopoly at retail level (above wholesale cost). Duplication and a possible reduction of the competitor's access cost to marginal network costs³⁶ would not impact the retail profits of the two firms, most importantly leaving the competitor's total profits unchanged. Duplication at any positive investment cost is therefore never possible in such an environment. In addition, a change in the distribution of bargaining power has here no effects as the competitor is indifferent about the level of the access charge.

When ex-post non-linear access prices are considered, for instance, not only a usage based charge has to be paid by the access seeker, but also a fixed charge. Compared to the linear access charge, more rent extraction would then be possible. As in a joint venture, the usage-based access charge would then be chosen high enough to set marginal cost conditions such to maximise

³⁶ both operators would then face this access cost instead of the access price and there would be no wholesale market anymore

industry profits (monopoly outcome), while the fixed fee would allow the participants to divide the profits according to bargaining power between the two firms (in case of full bargaining power, extracting the entire additional profit, being largely equivalent to a joint venture). A two part tariff option therefore increases the investment cost that can be borne by the investor and investment incentives for total coverage when compared to standard linear access charges. When a shift in bargaining power is considered, it has no direct effect on the market outcome, but on the distribution of rents (and indirectly on level of investment). When not all of the bargaining power is with the investor, rent extraction and total coverage are lower. Regarding duplication, when the entrant does not invest on its own and uses access it has zero profits under nonlinear access in case of full rent extraction. The decision on when to invest in duplication is for the entrant then equivalent to the case when no access is possible. The probability of duplication is therefore the same. It is however, reduced when the incumbent has not full bargaining power. In the extreme case where the incumbent has no bargaining power no duplication takes place. The fixed charge is then zero and the resulting contract equivalent to an ex-post linear access contract. Overall, non-linear contract types are therefore a useful instrument as they allow separating objectives maximising investment incentives.

Price dependent industry demand. In the more likely case when industry demand is price dependent an increase in the linear access price leads to higher retail prices but also a decrease of demand for the access seeking firm and the investor. There is therefore no one-to-one pass through anymore creating an asymmetry between the firms as the investor in its hinterland incurs only its marginal network cost and not an (above marginal cost) opportunity costs. The incumbent will therefore charge a lower uniform price than the competitor and have a relatively higher market share in the competitive segment (partial foreclosure). This outcome is therefore different to the outcome an integrated monopolist (joint venture) would prefer, creating allocative inefficiency and reducing overall rent extraction. As a consequence, duplication can now occur as the competitor's profits under duplication may be higher than under access, given that lower marginal costs would now allow the entrant to increase its demand, especially in its own hinterland. When the access seeking firm increases its bargaining power, finally, the contracted linear access price will be reduced, leading to lower retail prices of both firms and a relatively higher market share of the access seeker. With non-linear access prices instead, again, higher

investment incentives can be achieved. Setting a fixed charge, the incumbent can reduce the variable access fee returning to a more allocatively efficient and symmetric solution, while not being able to reach the joint venture allocation (as the incumbent cannot control the access conditions for both firms)³⁷. An optimal allocation without necessitating a joint venture allowing still full rent extraction could possibly be reached with an even more complex tariff foreseeing next to the fixed fee also the distribution of an adequately chosen ex-post lump sum transfer according market shares (similar to the “compensation mechanism” proposed by some Swiss operators).

Finally, when a linear or non-linear binding contract is instead signed ex-ante the competitor may commit to a usage-based and possibly also a fixed charge for access. When ex-ante negotiations break down, the outside profits depend on the outside option scenario (no access or linear or non-linear ex-post next generation access). Under ex-post contracts, as shown, a hold-up problem may arise, where not the entire rent can be extracted from the competitor in case the incumbent does not have full bargaining power. For the incumbent, the investment is then already sunk at the time of negotiation. It will therefore not be considered during an ex-post bargaining stage (e.g. Nash bargaining), the outside option being that only the incumbent offers next generation broadband based products. When ex-ante contracts are used, instead, investment costs are not sunk at the time of negotiation and the hold-up problem can be mitigated (and it even fully disappears with sufficiently complex contracts). Investment costs can therefore be shared somehow with the entrant.

The option for an ex-ante contract correspondingly increases the incumbent’s profits under-price independent demand, (weakly) increasing the range of investment costs that it can sustain and therefore total coverage when compared to the corresponding ex-post contracts. Also, duplication can be avoided, as under this ex-ante contract ex-post the fixed charge is already sunk, not creating any incentive for duplication for the competitor anymore.

Under price dependent demand, this result does not necessarily hold, as a reduction of the access cost from building own duplicated infrastructure can lead to an increase in the competitor’s demand, which may potentially be profitable. In case where a fixed contribution is sunk, this reduces, however, such incentives also in this case. Duplication is therefore in any case

³⁷ Changes in the bargaining power would here again not change the allocation.

more limited with ex-ante contracts. Overall, compared to ex-post contracts (and no access), ex-ante contracts in general provide higher investment incentives while minimizing duplication and dampening competition if the regulator does not put in place safeguards. This even occurs without considering uncertainty or risk aversion due to bargaining advantages.

3.3.4.2. Uncertainty. Inderst and Peitz (2013) consider a similar model as Inderst and Peitz (2012a), introducing uncertainty about the success of the investment. In addition, the effects of risk aversion and investment timing are analysed. Differently to Inderst and Peitz (2012a), however, duplication is a priori assumed to be not economically feasible, facilitating the analysis.

Uncertainty is introduced here by assuming that the next generation broadband gross utility is drawn from a distribution function with values equal to (in case of failure) or higher than the gross utility derived from copper (in case of success to the extent of the utility difference). When both operators use the next generation infrastructure with respect to the situation where copper is used, an increase in the gross utility of next generation broadband affects price and profits only under-price dependent demand.

Table 4 summarizes the predicted effects of different access options on investment incentives under uncertainty and risk neutrality, assuming that granting access generates value (net increase in industry profits), that is that there is sufficient expansion of total demand and/or lessening of competition so that foreclosure is not an optimal strategy for the incumbent.

Non-optional fixed fees. Under non-optional fixed fees, the access seeker enters a binding ex-ante agreement on an access charge plan and there is no opt-out possibility. It is assumed that after signing the contract a fixed charge (investment contribution) has to be paid by the competitor in any case and usage-based access will be granted ex-post at marginal cost (as in all other cases below when a fixed charge is considered). The access seeker is, however, free to buy zero quantity after realization of demand, meaning that only the fixed charge is non-optional. The allocation on the retail market would then be the same as under duplication (symmetric) as both competitors would enjoy marginal costs access to the infrastructure ex-post. The fixed contribution can have two effects on coverage. In case the incumbent's investment would be viable also without it (i.e. when the competitor would continue to use copper), total coverage is not affected. Access is still granted in this case as long as it creates added value for the industry

(extension of total demand and/or lessening of competition). In cases when the investment without the investment contribution of the competitor is not viable, coverage is, instead, extended when compared to a case without access. The operators will in this case be able to agree on an ex-ante fixed fee as long as industry profits with next generation broadband (both firms) exceed industry profits under copper (both firms) by more than the investment cost (via extension of total demand and/or lessening of competition). Such a scheme does, however, not provide for maximum investment incentives as differently to the optional plans described in later sections the outside option for the competitor is in one scenario based on copper reducing the incumbent's bargaining power and extractable rents³⁸.

Optional fixed fees. Under an optional unconditional fixed fee, the competitor has the possibility to seek access signing an access contract ex-post or also ex-ante, while it can then also opt out of the contract after uncertainty has resolved and it is known whether demand is high or low. The competitor accepts to pay the agreed fixed fee in case demand (gross utility from next generation services) turns out to be sufficiently high. In this case, in fact, its copper based profits would otherwise be too importantly reduced by customers switching to the incumbents next generation products. Conversely, when demand turns out to be sufficiently low, the competitor will continue to use regulated copper access, which is socially inefficient, reducing competition and not allowing any rent extraction for the incumbent. When demand turns out to be higher than the level to make the competitor's entry via next generation access viable, the competitor makes positive profits, which can, in addition, not be extracted by the incumbent with an unconditioned fee. The investor then receives the fixed contribution with the probability that demand realizes sufficiently high to make the next generation access contract viable for the competitor. If such a probability is low, the investor would have to increase the investment contribution to obtain a given fraction of the investment. But then again the level of demand necessary to sustain such a charge for the competitor increases, reducing the probability of success and so on. In other terms, it may be impossible for the incumbent to extract sufficient rent to sustain the investment with an

³⁸ It is also shown as an example that the access option of setting the non-optional ex-ante fixed charge at the investment cost multiplied by the expected market share of the competitor would not necessarily satisfy the participation constraint in the case when a single investment is not profitable but a co-investment is. There may therefore be cases where benefits and therefore the investment contribution would need to be distributed differently.

unconditional charge. In addition, this scheme could (at least ex-post) not efficiently address a hold-up problem when the incumbent has not full bargaining power.

Conditional fixed charges. The shortcomings of optional contracts can be overcome by conditioning the fixed charge on the realization of demand. When negotiations take place ex-post and after realization of demand for instance, the level of demand (gross utility for next generation broadband) can be observed and taken into account at the contracting stage, allowing an efficient adaption to market conditions and efficient surplus extraction. When the incumbent has full bargaining power it can then extract the entire profits the competitor generates from upgrading to the next generation infrastructure under any realization of demand. Next generation access is therefore always provided as long as industry profits increase with the introduction of the next generation network as assumed initially. When considering full bargaining power, rent extraction and efficiency is enhanced when compared to an ex-ante unconditional access option where in one scenario the outside option is copper not only for the competitor but also for the incumbent. Under conditional ex-post contracts, instead, the outside option is always next generation broadband for the incumbent, who has always already invested³⁹, and copper for the competitor, putting the competitor in a weaker position. The extractable gross profit from access for the competitor is therefore higher under conditional optional contracts.

As shown under certainty in Inderst and Peitz (2012a) with ex-post contracts, the investment incentives for the investor are, however, reduced when it does not have full bargaining power. Ex-ante contracts may solve also this hold-up problem. The same is true under uncertainty. Also, ex-post contracts were shown to be an efficient tool to extract rent as they can be fully conditioned on the actual realization of demand. In principle, it is possible to combine both schemes introducing flexible ex-ante contracts depending on demand realization (as long as the level contracted upon is not only observable but also verifiable ex-post). An optimal access option could therefore be an optional ex-ante contract conditioned on realised demand. In such a case, however, from a practical point of view a series of access prices would need to be defined ex-ante for all possible outcomes. Even though the negotiation here takes place ex-ante, the outside option considered is never that of no investment (where both firms use copper), as the

³⁹ or is foreseen to have invested

situations defined in the ex-ante contract apply only to situations when the investment would have already been undertaken. In this case the same efficiency as with ex-post contracts can be achieved with ex-ante contracts, while addressing in addition a possible hold-up problem. Compared to a non-optional ex-ante fee where in some cases the outside option consists in no investment by the incumbent and therefore relatively higher profits for the competitor when remaining on copper, the rent possibly extracted by the incumbent is therefore increased. When the outcome can be perfectly observed and verified, an ex-ante conditional optional fee would therefore provide the same investment incentives as an ex-post optional fee under full bargaining power. When instead the incumbent does not have full bargaining power the ex-ante optional conditional fixed charge is the most efficient tool to promote investment incentives, as it also addresses the hold-up problem. As will be seen in the next section, such an access scheme undermines, however, one of the main functions of a co-investment, which is to reduce the investor's risk, as the investor would in this case need to bear a larger share of the investment cost when demand turns out to be low. In the scenario considered in this section (risk neutrality) this effect needs not to be considered.

Inderst and Peitz (2013) also compare linear usage-based charges, assuming that the fixed charge is zero. In this case, any access plan is optional as the competitor could always opt-out by buying zero quantity. As shown under certainty, when demand is price dependent, usage-based charges introduce inefficient allocative asymmetries. Nevertheless, investment incentives compared to unconditional fixed fees with equivalent wholesale revenues are shown to be usually enhanced as usage-based charges provide conditional wholesale revenues by construction. Also, corresponding non-linear usage-based access charges can be considered. When still considering an access scheme that implies the same level of wholesale revenues than under the unconditional optional fixed charge and the linear usage-based charge, a non-linear charge such as quantity discount leads to relatively lower access prices when demand is high and relatively higher access charges when demand is low. This has two effects. On one hand, this creates an incentive for both firms to increase output when they use the next generation network, reducing deadweight loss and enhancing competition compared to the linear charge. This usually would lead to lower profits and investment incentives though. On the other hand, when demand is realized to be low, access charges increase relatively, meaning that the likelihood that the next generation infrastructure is used by the competitor is reduced and that usage is less efficient. Overall,

investment incentives seem to be lower in case of risk neutrality than with a corresponding linear usage-based charge. In addition, negative quantity discounts could also be considered. This is for instance the case with capacity limits, where once reached, higher per unit access costs need to be paid. The conclusions are similar to positive quantity discounts. Capacity constraints could therefore be efficient to increase investment incentives. The authors finally consider a combined fixed and usage-based charge under uncertainty. They propose a standard case of a non-optional fixed ex-ante fee and an ex-post optional usage based access fee. The usage based fee can as shown under certainty be used to relax competition in the retail market, increasing investment incentives, while the ex-ante non-optional fixed fee may be used to distribute rents especially when the incumbent does not have full bargaining power. However, with respect to the joint venture outcome in case of price dependent demand, there continues to exist an allocative inefficiency.

Risk aversion. Risk adverse firms consider profits less valuable when they are uncertain. The two competitors may also have different levels of risk aversion, for instance resulting from their varying ability to access the capital market. Inderst and Peitz (2013) then consider an ex-ante non-optional fixed fee (with the usual marginal cost usage-based charge) and alternatively a linear usage-based charge (above marginal cost) generating a priori the same wholesale revenues. In this case, when demand turns out to be high, it is shown that the investor has higher total profits under the usage-based charge than under the fixed charge. When demand turns out to be low, the investor would have lower profits under the usage-based charge. The profit function of the incumbent under a usage-based charge is therefore rotated with respect to profits under the fixed charge. The investor's profits with a fixed charge over all possible outcomes of demand are therefore less risky than under a usage-based charge. The latter therefore shifts more risk to the investor. Conversely, the risk the competitor would bear with a non-optional fixed fee would be the same as the investor's risk. If regulation aims at balancing risks between market participants such an access option could therefore be desirable⁴⁰ and depending on the extent of risk adversity of the incumbent this could increase investment incentives accordingly. When considering (unconditional) optional fixed charges instead the risk profiles changes radically. In this case when demand turns out to be low the competitor would opt not to ask for access. From a certain

⁴⁰ Abstracting from a possible foreclosure or late entrant problem.

level of demand, it would ask for access and pay the fixed fee. The investor's profit function is therefore shown to have a discontinuity (increase) at some level of realised next generation broadband gross utility. The level of the discontinuity depends on the level of competition. When there is weak competition (strong horizontal differentiation) the discontinuity corresponds nearly to the fixed charge implying a large revenue risk for the investor.

Finally, Inderst and Peitz (2013) also introduce a dynamic model, where demand for next generation broadband in the market is expected to exogenously grow over time, meaning that operators may prefer waiting some time before investing. Investment can in a basic scenario be seen as an initial decision causing a number of periods of profits depending on the realisations of demand for next generation broadband. Also, from the moment the competitor asks for access, it is supposed to need to pay a corresponding fixed charge also in each following period to access the network. This setting implies that there is an optimal moment for the competitor to invest and adopt next generation access, the moment being determined by the paths of the access charges and gross profits. Introducing uncertainty about the next generation broadband gross utility means, that waiting is becoming an even more attractive option. But, as the next generation network already exists, waiting is not socially optimal. Therefore, the fixed access charge should be set low initially and rise over time. This could then be an efficient access option for ensuring earliest possible next generation broadband adoption by the competitor while maximising investment incentives. In an additional scenario when the investor is allowed to dilute its investment over time and when cumulative investments are assumed to increase the likelihood of high next generation broadband gross utility realisations, there may – under uncertainty - also be value of waiting for the investor, especially for risk averse investors. Comparing a fixed to a linear usage-based fee in this context, it is shown that the latter may have an efficiency advantage over the former as it would increase with the competitor's subscribers over time while fixed revenues would remain constant. For a given level of investment contribution, the usage-based fee may, therefore, lead to relatively earlier investments and more efficiency.

3.3.5. Empirical literature. Empirical data on the effectiveness on new regulatory options such as co-investments is not yet available as such options have only been introduced very recently. Krämer & Vogelsang (2012) provide, however, a laboratory experiment on the effects of a co-investment option in the market which can be empirically analysed. In their model two firms

determine the coverage of their next generation access networks in a Greenfield in three areas: metropolitan, urban and rural (respectively increasing in investment costs per household). Depending on the scenario a firm can roll-out independently or (partially) cooperatively. In subsequent ten stages firms compete repeatedly in a retail market with homogeneous goods (Bertrand) in all areas where they have own infrastructure or access (at a geographically uniform price). When the price of two operators is the same, customers are supposed to have a higher probability to choose the incumbent (75%). Access regulation (LRIC⁴¹) is exogenous and assumed to be in effect wherever only one firm is present (single infrastructure area). In the scenario without a co-investment option the incumbent first and then the entrant decide on their independent coverage. When instead a co-investments option is admitted, the two firms can, in a prior stage, agree bindingly on the area they will cover by co-investment (basic investment sharing, where the total investment cost for the infrastructure is assumed to remain unchanged). After agreeing on a co-investment, the operators again choose their independent coverage. Under these model settings in the last stage prices would in equilibrium be competed down to marginal costs and the market would be split. In a finitely repeated setting the unique equilibrium of the whole retail game is equivalent. The marginal cost to which prices are competed down includes, however, not only the average marginal cost for access on the other operator's network but also the opportunity cost in form of an own (average) access price (represented by the average marginal cost for access for the other operator). This is the case, as giving up a customer implies that the operator does not have to pay an (average) access fee anymore, but that in turn it will receive an (average) access fee. Regarding the investment stage, under the independent investment scheme the authors find that the first mover advantage of the incumbent leads to an equilibrium such that it would cover all possibly profitable areas with own infrastructure anticipating that uncovered profitable areas would otherwise be covered by the entrant (in which case its overall profits would decrease as it would have to pay a positive return on investment to the entrant for access). It is also found that the entrant having the same cost structure would find it unprofitable to invest in additional areas and that duplication is not feasible as the entrant would need to pay investment costs in own infrastructure without being able to obtain any benefit (no wholesale profits and retail profits are always zero). In equilibrium, therefore, the incumbent rolls out as far as profitable alone and the entrant asks for access. In the investment stage under

⁴¹ including a return on investment

the scheme which foresees the possibility for co-investment the equilibrium outcome is surprisingly shown to be identical. As a co-investor, the entrant would have access to the infrastructure at marginal costs not needing to pay any return on investment to the incumbent via an access charge. When deciding for co-investment, however, wholesale profits are the only real benefit of investment as retail prices are competed down to marginal cost. Any extent of co-investment would therefore reduce the overall profitability of the infrastructure. Thus, co-investment is fully avoided in equilibrium. After unsuccessful co-investment talks, the equilibrium outcome would then be the same as under independent investment with the incumbent covering all profitable areas and the entrant asking for regulated access.

In a laboratory experiment the authors then tried to evaluate differences between these scenarios. In addition to the scenarios described, the participants in the experiment were also exposed to an outside scenario under independent investment with communication where otherwise similar to the co-investment scenario they could also communicate before the investment stage (but not make a co-investment contract). Such a scheme is unlikely to exist in reality. In both cases, however, participants were not allowed to communicate prices (Chinese wall). In a first empirical model, a mixed-effects linear regression is used to test for differences in total coverage and collusion across different scenarios (Table 5).

In a first econometric analysis, it is found that in an artificial scenario with independent investment, the possibility of communication leads to highest total coverage. The co-investment option scheme leads to less but not statistically significantly different total coverage, when compared to the standard independent investment scenario. Interestingly, even though not an equilibrium outcome under the co-investment option, 56% of duopolies chose to co-invest. This could be motivated by the second result. The authors also use the model to test for differences in the average level of price collusion (over ten periods) in form of a simple Lerner index and a variant of the Lerner index measuring the deviation from average costs. The result shows that collusion is significantly higher in the scenario with a co-investment option present when compared to the other scenarios. Finally, a three level model is estimated considering single periods. These regressions show that tacit collusion decreases towards the end of the game. The authors suspect, however, that this is due to the finite nature of the game. More importantly, it is shown that collusion increases from round to round. Therefore, the longer the participants are in the market, the more they learn to collude.

In a second econometric analysis, the influence of actual market outcomes such as the share of co-investment coverage (rather than differences in scenarios) on total coverage, prices and consumer welfare is estimated. The authors state that they did not impose any demand or cost shocks, meaning that differences in prices or total coverage could be caused only by the conduct of the firms (collusion and investment levels). They assume therefore the absence of any endogeneity problem and use simple regressions where the explanatory variables are treated as exogenous. Such a fully exogenous setting is unlikely to be realistic and results could be unstable. The most important results seem, however, to broadly support the preceding analysis indicating that the possibility of communication per se significantly increases coverage. Moreover, the share of co-investment coverage (excluding effects related to communication) would not increase total coverage. Regarding collusion, it is found that the share of duplication as expected reduces the level of collusion while co-investment increases it (even net of communications effects). The authors see the latter effect as a mystery and speculate about a psychological result from a stronger bond between the two firms in the case of co-investment. Overall they show that consumer welfare can be increased via co-investment when regulators are able to hold these collusive effects in check.

3.4. Discussion

In this section the conclusions holding throughout the literature and possible future work in this field are discussed. Directly comparing the results of the theoretical literature is a complex task as fundamentally different market models and co-investment agreement details are considered. Despite these differences, however, the conclusions and recommendations offered by the literature are surprisingly consistent.

Generally, co-investment agreements are shown to always increase investment incentives in duopoly coverage when compared to no access, while usually not having an impact on total coverage. Total coverage can, however, be affected also with co-investment agreements when compared to the outside option, as they can be used to reduce downstream competition (via internal and/or external access prices, by communication or other means), to extract more rent from access seekers, to extend total demand or in case of risk averse operators to share risks. The fine details of such agreements as well as of the considered outside options therefore matter.

Cambini and Silvestri (2013) show that under certainty and without outsiders, basic sharing is superior to next generation access regulation at marginal cost in terms of welfare, increasing both investment levels and competition, as the competitors' profits may also be taken into account in the investment decision thereby expanding network coverage at unchanged access conditions. These results remain valid when outsiders are considered even though co-investment schemes can then lead to foreclosure.

Analysis of Ribeiro (2016) largely supports Cambini and Silvestri (2013) with some complementary results. According to these results that are based on a four operator setting, market exclusion of the facility-based operator (outsider) has not been found whereas the service-based operator (second outsider) is excluded from the retail market when the wholesale access price is unregulated. Ribeiro (2016) also finds that an asymmetric regulatory intervention at the wholesale access price level is justified as a means of improving social welfare if the investment effort is excessively high. His findings as to partial integration highly support those of Cambini and Silvestri (2013), also noting that full integration is socially desirable when the gap between fibre and cable spill-overs is sufficiently low.

Under uncertainty, without outsiders, when there is differing ability to increase willingness to pay of consumers across firms, positive co-relation (increase of both investment levels and competition) remains substantially valid according to Cambini and Silvestri (2012). Basic sharing would still provide maximum output while investment incentives are reduced. When the regulator would set the access price at marginal cost, however, basic sharing would continue to provide also higher investment incentives. When the competitor is slightly better than the incumbent in selling next generation services (a regulator would then set the access price to zero), basic sharing continues overall to be the socially optimal choice. When instead the incumbent is (slightly) better, basic sharing is still a better choice than traditional regulation (but not necessarily than deregulation). Nietsche and Wiethaus (2011) find that with equal ability to increase willingness to pay of consumers across firms in terms of consumer welfare, this conclusion remains valid for different forms of access regulation (in particular LRIC and FDC).

These different authors seem to agree that basic sharing may represent a valid alternative to traditional access regulation. A basic sharing option could in practice be implemented by imposing regulated conditions to next generation access roll-out joint ventures, which includes

the imposition of an internal ex-post access fees and the split of investment costs. In substance, this is the regulatory scheme implemented in France. The question then arises, however, whether a solution where ex-post regulated next generation access to the infrastructure is continued in parallel to such regulation would not be an even better solution⁴².

From the literature only few conclusions can be obtained regarding co-investment schemes under parallel traditional usage-based next generation access regulation environment. Only Bourreau et al. (2013) analyse such a setting. They conclude that with uncertainty and outsiders, deregulation of basic sharing agreements (i.e. no ex-post regulation of the outsider access price) may be socially preferable to access regulation only when services are highly differentiated and the access charge under regulation would be high. This is the case because with outsiders dampening of competition takes place also under basic sharing. Nevertheless, there are some specific circumstances under which deregulation can be a welfare optimal solution in presence of such a co-investment scheme.

Regulators should therefore consider the possibility of deregulation of co-investments and articulate ex-ante which detailed forms of co-investments would warrant which type of deregulation and under which circumstances. In light of the above result it seems, however, likely that the introduction of a regulated co-investment option should usually be accompanied by continued traditional next generation access regulation to hold excessive negative competitive effects - due to the presence of outsiders - in check⁴³. This is also the approach the French regulator has chosen.

Regarding long-term access options Inderst and Peitz (2012a) show that, under certainty, with price independent demand and full bargaining power, non-linear ex-post access fees can increase rent extraction over linear access prices to the point to reach investment incentives under monopoly (joint venture). This is the case because with price independent demand, no allocative inefficiencies from access arise. When instead industry demand is price dependent, there is an inherent allocative inefficiency, implying that under any form of (long term) access, investment

⁴² as in the French case

⁴³ It should be noted here that Cambini and Silvestri (2013) show that when considering basic sharing as an alternative to traditional regulation with outsiders, basic sharing would be preferable for regulators to access regulation (at marginal cost) even though this may imply foreclosure.

incentives are reduced. Under these circumstances, a highly complex contract with lump-sum compensation payments based on ex-post market shares can possibly achieve replication of the monopoly outcome under full bargaining power and certainty. Finally, ex-ante contracts increase investment incentives for any tariff plan when the incumbent does not have full bargaining power, making rent extraction always more efficient.

Under uncertainty, instead, Inderst and Peitz (2013) show that the above is no longer true and that fixed unconditional fees are inefficient, as when demand turns out to be low the competitor would continue to use the copper network. Competition as well as investment incentives could, however, be enhanced when it would be given access at reasonable terms. Conditional fees are therefore more efficient in this case. Conditional fees can also be defined ex-ante (describing all possible outcomes), additionally addressing a possible hold-up problem. Ex-ante optional conditional fixed fees are therefore the most efficient (fixed only) access option to promote investment incentives under risk neutrality. Finally, when the investor is known to be risk averse and regulation aims at balancing risks between market participants a largely non-optional ex-ante fee becomes again an interesting access option promoting investment.

The empirical literature on the subject is still very limited. In Krämer & Vogelsang (2012) co-investment is not taking place in equilibrium due to unrealistically aggressive retail competition assumptions when compared to the rest of the literature. Unsurprisingly, their experimental results suggest that such equilibrium would not arise in reality and that operators may use co-investment as a means to increase collusion - even when the internal access fee is fixed at marginal cost and in presence of Chinese walls limiting communication.

To conclude, on the subject of next generation broadband co-investments many issues still remain to be explored. The most important flaw when comparing theoretical literature with applied regulation seems that multifibre has not yet received attention in academic research. Given the attention this roll-out option has received from regulators as well as Governments and the European Commission, future co-investment models should try to incorporate realistic multifibre options. The main properties of multifibre, which could allow integration in existing models, are that it allows more flexibility and independence via infeasible rights of use when compared to traditional networks, that it enables consumers to purchase services from multiple

providers simultaneously and that switching costs are reduced. More concretely, multifibre may allow physical infrastructure competition between the partners to a large extent. In the existing literature usually under joint ventures a common access price to the infrastructure for outsiders is chosen by the partners jointly and under long-term access an incumbent is setting this price (alone). With multifibre, instead, both types of outsider access charges could be set independently by the two partners. In addition, another form of access debated by regulators has not yet received attention. Participation in a co-investment agreement would also be possible ex-post. Such a scenario seems particularly relevant in the multifibre case, where for instance in Switzerland two dedicated fibres (out of four) are today often left unused. Also, the co-investment compensation mechanism described in the section on regulatory practice has been only broadly explored by Inderst and Peitz (2013). It should be analysed in more detail in a fully-fledged model. Finally, there has yet been no common framework proposed which allows for a direct comparison of the joint venture cases (e.g. Netherlands) to long-term access agreements (e.g. Switzerland) considering the practical regulatory contexts in the different countries.

4. Concluding remarks

This chapter integrates themes which have appeared throughout the text.

The review of practical cases has shown that by mid 2016, European regulators continued to lack clarity on how to handle co-investment agreements and geographic regulation. At the time of writing, a wide variety of regulations were being applied. Their ultimate success will not be evident until several years after their implementation. To cite only the most extreme cases which have been reviewed:

- Regarding co-investment, on one hand, the Swiss regulator leaves full freedom to co-investors to shape their next generation access network risk sharing agreements (as long as compatible with cartel law). On the other hand, the French regulator regulates all important clauses of such agreements (share of investment cost to bear, access price for insiders and outsiders, location of distribution point).

To date, there do not appear to be strong initiatives to address these issues at the European level. It is possible that this is the case as regulators, BEREC and the European Commission do

not yet have a clear vision on these issues. This is understandable to some extent, as for example the analysed effects of co-investment schemes depend on the fine details of such agreements and often also on market parameters such as the willingness to pay, investment requirements or potential industry demand expansion. While the economic literature on these topics is still limited, it seems, however, to clearly show that co-investment agreements with the right clauses can enhance welfare over traditional regulation at least in some cases. Future literature will likely further build on this and provide more insights. Nevertheless, it seems that regulators are now in a position to start to reflect on how to better promote co-investments and investment incentives in general.

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Table 1

Fibre Greenfield deployment costs per home connected and passed, FTTH P2P (source: WIK)

Type of investment cost	Germany	France	Sweden	Portugal	Spain	Italy	Switzerland
FTTH investment cost (homes connected)	2'111€	2'025€	1'333€	1'548€	1'882€	1'160€	1'643€ (2'465 Fr.) ⁴⁴
FTTH investment cost (homes passed)	919€	930€	530€	776€	859€	504€	-

⁴⁴ Ilic, Neumann and Plückebaum (2009) show that in Switzerland the investment per home connected in an urban area (the comparable Swiss cluster is cluster 2) is 1'643€ per month. It is however considered that FTTH would reach a market share of 75% and not 50% as in the other cases as this is assumed to be more realistic in the Swiss case. Calculating a comparable value, deployment costs in Switzerland would be around 2'000€ and therefore comparable to Germany or France. The exchange rate was assumed to be 1.50 Fr./€. When applying a more recent 2013 exchange rate (1.20 Fr./€) deployment costs would be comparably highest with around 2'500€.

Table 2

Investment incentives from non-cooperative and cooperative access innovation

Type of access contract	Cooperative access innovation	Non-cooperative access innovation
Fixed usage-based access charge	Lower investment incentives	Higher investment incentives
Linear ex-post contracts with high spill-overs	Higher investment incentives	Lower investment incentives
Linear ex-post contracts with low spill-overs	Lower investment incentives	Higher investment incentives
Standard LRIC	Higher investment incentives (higher total welfare)	Lower investment incentives (lower total welfare)

Table 3

Effect of access options under certainty (only case of price independent demand)

Type of contract	Investment incentives (total coverage)	Investment incentives (duplication)
No access possibility	Lowest	Maximum
Ex-post: Linear access charge	Intermediate	None
Ex-post: Nonlinear access charge (full bargaining power with investor)	Maximum	Maximum
Ex-post: Nonlinear access charge (not full bargaining power with investor)	Intermediate (equal or higher than with linear access charge)	Intermediate
Ex-ante contract option (co-investment)	Higher than corresponding ex-post option	None

Table 4

Effects of different access options on investment incentives under uncertainty and risk neutrality

Type of contract	Hold-up problem	Usage of NGN by competitor in all cases	Competitor's outside option	Overall NGN investment incentives
Fixed access charges unconditional on NGN gross utility				
1) - Ex-ante contract - Non-optional fixed charge unconditional on demand	Efficient	No	Incumbent: NGN/copper Competitor: copper	Intermediate
2) - Ex-post contract (before realisation of demand) - Optional fixed charge unconditional on demand	Inefficient	No	Incumbent: NGN Competitor: copper	Low
Fixed access charges conditional on realisation of NGN gross utility				
3) - Ex-post contract (after realisation) - Optional fixed charge conditional on demand	Inefficient	Yes	Incumbent: NGN Competitor: copper	Intermediate (maximum with full bargaining power)
4) - Ex-ante contract - Optional fixed charge conditional on demand	Efficient	Yes	Incumbent: NGN Competitor: copper	Maximum
5) - No fixed charge - Linear usage-based charge	Inefficient	Yes	Incumbent: NGN Competitor: copper	Intermediate (but higher than unconditional fixed fee)
6) - No fixed charge - Nonlinear usage-based charge	Inefficient	Yes	Incumbent: NGN Competitor: copper	Lower than than linear usage-based charges

Table 5

Experimental results, effect of availability of options on competition and investment

Option	Investment (total coverage)	Intensity of Competition
Co-investment option	Intermediate	Lowest
Independent networks investment option	Intermediate	Intermediate
Independent networks investment option – with limited communication possibility	Maximum	Intermediate

Table 6
Theoretical analyses – Next generation access network co-investments

Cooperation type	Article	Main assumptions						Main results
		Fixed investment contribution (share of investment cost)	Usage-based access charges for insiders	Usage-based access charges for outsiders	Uncertainty	Old technology	Effect of NGN	
Joint venture (JV)	Cambini & Silvestri (2013)	Yes, equal shares	Yes (free choice)	Yes, positive and higher than insider fee	No	Yes	NGN increases willingness to pay (same for both firms) depending on investment extent	Cambini and Silvestri (2013) show that without outsiders, basic sharing is superior to NGN access regulation at marginal cost in terms of welfare, increasing both investment levels and competition, as the competitor's profits may also be taken into account in the investment decision, thereby expanding network coverage at unchanged access conditions. These results remain valid when outsiders are considered even though co-investment schemes can then lead to foreclosure.
	Cambini & Silvestri (2012)	Yes, variable shares.	Yes (free choice)	-	Yes	Yes	Chance that NGN investment increases willingness to pay (by same amount for both firms)	Under uncertainty, without outsiders, when there is differing ability to increase the willingness to pay of consumers across firms, basic sharing always leads to more competition and output than regulation or deregulation while full deregulation induces the highest investments. From a welfare point of view, when the competitor is better than the incumbent in providing NGN services (and the regulator would consequently set the NGN access price under full regulation to zero) basic sharing is always optimal. When instead the incumbent is better, the ranking is less clear. Basic sharing usually continues to be optimal.
	Cambini & Silvestri (2013)	(see above)	Yes, marginal cost	(see above)	(see above)	(see above)	(see above)	(see above)

Basic investment sharing (particular form of JV)	Nietsche & Wiethaus (2011)	Yes, equal shares	Yes, marginal cost	-	Yes	Yes	Chance that NGN investment increases willingness to pay (by same amount for both firms)	Risk sharing (basic sharing) is shown to lead to maximum output and competition as well as to maximum consumer welfare, when compared to LRIC, FDC or deregulation for its strong competitive effects and reasonable investment incentives allowing the operators to share benefits and costs upfront even if ex-post the investment fails.
	Bourreau, Cambini & Hoernig (2013)	Yes, equal shares	Yes, marginal cost	Yes, same as insider fee	Yes	No	Demand for NGN can be high or low (same willingness to pay across firms)	With uncertainty and outsiders deregulation of basic sharing agreements (i.e. no ex-post regulation of the outsider access price) may be socially preferable to access regulation only when services are highly differentiated and the access charge under regulation would be high. This is the case because with outsiders dampening of competition takes place also under basic sharing. Nevertheless, there are some circumstances under which deregulation can be a welfare optimal solution in presence of such a co-investment scheme.
	Krämer & Vogel-sang (2012)	Yes, 75% incumbent / 50% competitor (demand share)	Yes, marginal cost	-	No	No	No quality effect, willingness to pay is identical for both firms	Basic sharing is not taking place in equilibrium due to aggressive downstream retail competition assumptions when compared to the rest of the literature. Experimental results suggest that such equilibrium would not arise in reality and that operators may use co-investments here as a means to increase collusion - even when the access fee is fixed at marginal cost and in presence of Chinese walls limiting communication. Overall the regulator can ensure positive effects on consumer welfare when the introduction of a co-investment option is accompanied by measures preventing collusion.
Access innovation joint venture	Mizuno (2009)	Yes, variable	Incumbent has access at marginal cost. Competitor has access at regulated prices (fixed multiple of	-	No	No	NGN investments have no effect on quality but can reduce marginal costs	Under a regulated (usage) cost based access pricing rule when positive spill-overs from access innovation on the entrant (via a cost oriented access charge) are sufficiently high, the entrant also benefits from a reduction in access costs. In this case the negative effects from more competition (in this range the incumbent's marginal costs decrease more than the entrant's) are sufficiently balanced. Then the entrant may participate in a cooperative investment scheme increasing overall investment incentives. The author moreover shows that in case of standard LRIC cooperation is enhancing total welfare. Finally he shows that investment incentives under no cooperation can be

			marginal cost)					enhanced with a two-part tariff but that this would not be welfare optimal.
Long term access	Inderst & Peitz (2012a)	-	Incumbent has access at marginal cost. Competitor has access at possibly above marginal cost prices.	-	No	Yes	NGN increases consumers gross utility of the service (same amount for both operators).	Under certainty, with price independent demand and full bargaining power non-linear ex-post access fees can increase rent extraction over linear access prices to the point to reach investment incentives under monopoly (joint venture). This is the case because under price-independent demand, no allocative inefficiencies from access arise. When instead industry demand is price dependent, there is an inherent allocative inefficiency, implying that under any form of (long term) access, investment incentives are reduced. Under these circumstances, a highly complex contract with lump-sum compensation payments based on ex-post market shares can possibly achieve replication of the monopoly outcome under full bargaining power and certainty. Finally, ex-ante contracts increase investment incentives for any tariff plan when the incumbent does not have full bargaining power, making rent extraction always more efficient.
	Inderst & Peitz (2013)	-	Incumbent has access at marginal cost. Competitor has access at possibly different access options.	-	Yes	Yes	NGN increases consumers gross utility of the service (same amount for both operators).	Under uncertainty, instead, the conclusions of Inderst and Peitz (2012a) are no longer valid and fixed unconditional fees are inefficient. When demand turns out to be low the competitor would continue to use the copper network. Competition as well as investment incentives could, however, be enhanced when it would be given access at reasonable terms. Conditional fees are therefore more efficient in this case. Conditional fees can also be defined ex-ante (describing all possible outcomes), additionally addressing a possible hold-up problem. Ex-ante optional conditional fixed fees (with subsequent access at marginal cost) are therefore the most efficient access option to promote investment incentives under risk neutrality. Finally, with risk aversion, profits are less valuable when they are uncertain. When the investor is known to be risk averse and regulation aims at balancing risks between market participants a largely non-optional ex-ante fee becomes again an interesting access option promoting investments.