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Abstract

This paper presents a model of competition between an incumbent firm and an Other Licensed Operator (OLO) in the broadband market, where the incumbent has an investment option to build a Next Generation network (NGN) and it can do so by making an investment sharing agreement with the OLO, or alone. Two different kinds of investment sharing contractual forms are analysed, a basic investment sharing, where no side-payment is given for the use of the NGN between co-investors, and joint-venture, where a side-payment is set by the co-investing firms. Results show that investment sharing can potentially be beneficial in terms of competition and investments, but the number of firms involved matters and so does the choice of the NGN access price, for insiders and outsiders of the agreement. Even when the presence of firms outside of the agreement force insiders to compete more fiercely, there might be a concern with the potential exclusion of the outsiders from the NGN.

Keywords: Investment, Regulation, Access pricing, New Technology, Risk Sharing

JEL Classification: L51, L96

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1 Introduction

The telecommunications markets currently face a period of widespread debate about the deployment of the so-called Next Generation Networks (NGNs). These networks represent a decisive progress in the telecommunications technology, due to their enhanced possibilities in offering faster transmission, and thereof services which demand more capacity and faster connectivity, such as interactive TV-centric and gaming broadband services, IP-based and high definition TV.

The issue of NGN deployment acquires a status of social interest at European and national level, due to the recognised importance of telecommunications infrastructures for economic growth (Röller and Waverman (2001), Koutroumpis (2009), Czernich et al. (2011)).[1] The European Commission dedicated a special effort to the development of digital markets in the European arena, setting ambitious targets in the document "A Digital Agenda for Europe" (COM (2010)245).[2] The issues related to the roll-out of new access fiber networks and the replacement of the existing copper networks regard mainly the high sunk costs for the construction and the uncertainty of returns due to market and regulatory risk. For these reasons, telecommunications operators are deterred from investing in such new technology. The European Commission and the national telecommunications authorities face new regulatory challenges with respect to the previous market scenario with only copper networks. The challenge is now not only to ensure that viable competition is working in the market, but also that conditions are such that investment incentives are stimulated. The classic trade-off between static efficiency and dynamic efficiency emerges.

Much of the debate on supply side policies focuses on what kind of access regulation should be set for the NGN and the rules regarding co-investment agreements between firms (Bourreau, Cambini and Hoernig (2012a; 2012b)). In fact, given the market and regulatory risks and the extensive investment requirements for the NGN roll-out, the opportunities of cooperative joint investments have recently become a

[1] Koutroumpis (2009) shows that the average impact of broadband infrastructure on GDP is 0.63% (for the EU-15, 2002-2007), that is the 16.92% of total growth of this period. Czernich et al. (2011) show that a 10 percentage point in broadband penetration increases annual per-capita GDP growth by 0.9% to 1.5%.

[2] In particular, the goal is to provide all European households with a broadband access of 30 MBit/s and at least half of all European households with a broadband access of 100 MBit/s by the year 2020.

prominent topic of discussion. Such co-investments are believed to possibly be a solution to the asymmetric risk allocation, which slows down the NGN roll-out, and to the financial constraints faced by firms. The discussion over co-investment agreements regards their effective superiority in terms of social outcomes and what rules for such agreements should be set to avoid potential anti-competitive consequences or, more generally, to maximise their social benefit. To this aim, a special attention must be devoted to the access conditions between partners: compensations mechanisms, exchange of information, non-discrimination clauses. It is also important to consider what is the number of players in the market compared to what is the number of co-investment partners.[3] European national authorities are adjusting their regulatory frameworks to include provisions regarding such co-investment agreements between telecommunications operators, to avoid inefficient investment duplications and at the same time potential anticompetitive consequences from cooperation between firms. One of the most sophisticated set of rules in this respect is represented by the French regulation. In France, in the "high-density areas", the regulatory authorities have set the following procedure for the NGN roll-out: (i) the initiator should first identify which other market operators are interested in co-funding the NGN investment; (ii) if no other firms participated in the investment effort, the investing firm is forced to give access at "reasonable and non-discriminatory condition"; (iii) if at least one other firm participated in the investment effort, they are forced to give access to late entrants, but the access price should be inclusive of a "risk premium" (Arcep (2009); Bourreau, Cambini and Hoernig (2010)).

A thorough analysis of these relevant factors regarding co-investment agreements for the NGN roll-out is still missing in the economic literature on regulation and investment in telecommunications; this paper aims at filling this gap.

Existing papers address the impact of access regulation on NGN investment in different perspectives.[4] Nitsche and Wiethaus (2011) compare different regulatory regimes regarding the effects on investment incentives, the competition intensity and the resulting consumer surplus in a two-stage Cournot model with two firms, a vertically integrated incumbent and an access seeking entrant, in a context with demand

[3]All of these factors are examined related to their impact in terms of potential anti-competitive behaviour of the partner firms in the Report on Co-investment Agreements published by BEREC (2012).

[4]Additional papers recently analyze how access rules affect the migration from an old "copper" to a new NGN infrastructure. See for example Bourreau et al. (2012) and Brito et al.(2012).

uncertainty. Risk sharing is one of the regimes they look at in their analysis, but it is considered in a reduced-form fashion, in which the two co-investing firms share the cost of the investment and then do not have to make any further side payment for the use of the NGN. However, they conclude that risk sharing can be particularly beneficial both in terms of investment incentives and consumer welfare. Cambini and Silvestri (2012) use a similar model to Nitsche and Wiethaus (2011), but analyse a dynamic framework with vertically differentiated firms. The paper extends the previous analysis and finds similar results regarding the potential benefits of risk sharing agreements. Nitsche and Wiethaus (2010) also wrote a White Paper that contains a discussion over possible extensions of their basic model, and an overview of the results when considering alternative approaches to risk sharing. In particular, they focus on different compensation mechanisms between the co-investing firms, each time considering separately: the presence of asymmetry between co-investing firms (market share asymmetry or risk commitment asymmetry); the presence of outsiders without access to the agreement; and the effect of changing the number of outsiders and insiders to the agreement on the final outcome of the model. Interestingly, Nitsche and Wiethaus (2010) also consider the potentially depressing effect on NGN investment incentives of a non-margin squeeze obligation, in case the investment turned out to be unsuccessful, while the other relevant papers assume no regulation at retail level. However, their discussion does not contain any analytical solution and the chance to have outsiders with access to the NGN is only discussed, because their model could not give an insightful numerical solution to the case.

Among the vast literature on network investment and regulation in telecommunications, there are few papers addressing directly the effect of different forms of co-investment agreements. Inderst and Peitz (2012) analyse the role of different contract types and access regulation on innovation and competition in NGN investment. In their model, an incumbent and an alternative operator (other licensed operator - OLO hereafter) can possibly invest in building a NGN, cooperatively or on a stand-alone fashion. They show that access contracts signed after the investment deployment lead less often to the duplication of investment and a wider roll-out, compared to a market where it is not possible to sign access contracts. In comparison to such ex post contracts, contracts signed before the investment deployment lead to an even wider roll-out and to a less frequent duplication of investments. However, both types of contracts can be used to dampen competition.

Bender (2011) examines a model inspired by Nitsche and Wiethaus (2011) but in a framework with horizontal product differentiation with price competition between an investing and an access seeking firm. In a context of uncertainty about the success of the NGN, he compares regulatory regimes with symmetric and asymmetric risk allocation, where the firms always have the opportunity to cooperate and jointly roll-out the NGN. Notably, he also analyses whether the firms are willing to cooperate in the investment deployment, as they cannot be forced to do so by regulatory authorities. However, he does not look into the different possible forms of compensation schemes for the use of NGN in the co-investment agreement, but rather, the risk sharing contract is modeled as a fixed transfer payment from the OLO to the incumbent. Kraemer and Vogelsang (2012) show the results of a laboratory experiment stating that co-investment increases investment with respect to access regulation but it also facilitates collusion. Finally, Bourreau, Cambini and Hoernig (2012b) analyse cooperative investment in a NGN and how it interacts with access obligations in presence of demand uncertainty. They show that co-investment only increases total coverage if service differentiation and/or cost savings from joint investment, in particular due to high uncertainty, are high. Mandated access reduces incentives for co-investment not only through lower returns but also by creating the option to ask for access instead. Voluntary access provision instead increases infrastructure coverage but reduces social welfare in local areas by softening competition if services are almost homogeneous.

The issue of the co-investment agreements relates also to the R&D literature, although regulation is not a stake there. Lerner and Tirole (2004) and Choi (2010)[5] consider a model where: (i) some firms form a research joint venture; (ii) the research joint venture offers licenses of its technology to the outsiders of the agreement. This literature analyses whether patent pools are welfare-enhancing, and hence, whether they should be authorized or not by competition authorities. The perspective though is ex post, i.e. innovations have already been done, and the question is whether pooling them is welfare beneficial. Also, usually the firms considered are not vertically integrated, as in the telecommunications markets, and they are not subject to regulation.

This paper analyses two different approaches to co-investment compensation

[5]Choi's paper provides a simple model that represents a simplification of Lerner and Tirole (2004).

mechanisms between an incumbent and an alternative operator, and their effect on the final outcome, in terms of consumer welfare and investments: basic investment sharing, where the firms share the investment cost and do not pay each other any compensation for the use of the NGN; joint-venture, where the firms share the investment cost and then set an internal access charge for the use of the NGN that maximises their joint profits[6]. A multi-stage static model where firms are symmetric is adopted and it is also assumed - for simplicity and to complement existing studies by Nietsche and Wiethaus (2011) and Bourreau, Cambini and Hoernig (2012b) - that there is no uncertainty on the market success of NGN. Regulatory commitment is only partial: firms know that the regulator is able to commit to a certain regulatory regime, but not to a predetermined level of the access charge to the NGN. For this reason, if the internal access charge is regulated, the authority decides upon the level of the access charge after the investment is deployed. Though closer to the Nitsche and Wiethaus (2011)'s paper, this paper focuses on the implications of more complicated structures of the co-investment agreements, in terms of alternative compensation schemes for the use of the NGN.

The results show that investment sharing is the socially preferable option in most cases. Basic investment sharing in particular seems to be beneficial as it ensures more competition than joint-venture and fairly high investment incentives. Joint-venture gives relatively higher investment incentives, but it carries more risks in terms of anticompetitive effects of the investment cooperation agreements. In particular, when all firms in the market participate to it, a joint-venture agreement can sensibly reduce competition downstream. When an outsider firm with right to ask access to the NGN is introduced in the final market, after the co-investment agreement has already been made and the investment deployed, the result shows that the risk of anticompetitive effects decreases, but there might be exclusion of the outsider from the NGN through high access price. If the regulator's objective is reaching a stage where all firms use the NGN, and so the copper network can be switched off, then a light regulation imposing no exclusion would be advisable.

The remainder of the paper is organised as follows. Section 2 provides the setup of the model with only the two co-investing firms as a benchmark situation. Section

[6]In order to focus on the specificities of the investment sharing agreements, this paper does not deal with the case where *both* the incumbent and the entrant invest, since this issue has been already analysed in several other studies (see, for example, Gans, 2007; Vareda and Hoernig, 2010; Bourreau et al. 2012).

3 examines the model with the introduction of a firm outsider to the co-investment agreement and explains the main findings under various regulatory circumstances. Section 4 summarises the paper and concludes.

2 Model

2.1 Basic Framework

There are two firms providing broadband connectivity in the retail market. One is a vertically integrated incumbent firm which owns the existing infrastructure. The other one is an OLO which competes via services in the downstream market and leases lines from the incumbent in the upstream market. Both firms provide the same services. The incumbent has an investment option to upgrade its existing network to an NGN, which allows for the convergence of better and more value-added services for voice, data and video. The extent of such investment can be either the whole network or just a part of it, which is a choice made by the incumbent. This is a one-time decision and once it is made, there is no possibility of further expansion in a later period. Alternatively, the incumbent and the OLO can cooperate and jointly roll-out the NGN by making a co-investment agreement. Such agreement can take different forms: basic investment sharing (B), where the firms share the investment cost and then are entitled to use the NGN without having to make any side payments; joint-venture (JV), where the firms share the investment cost and then pay a fee for the use of the NGN to the joint venture consortium entity, whose level is decided by maximising their joint profits as a co-investment consortium. If the incumbent invests in the NGN on a stand-alone basis, then it is forced to give access to the OLO at regulated conditions. Furthermore, it is considered the presence of a late entrant (outsider) in the market. It is assumed that the members of the co-investment agreement are forced to provide the late entrant with access to the NGN, and the access conditions can be regulated or chosen by the insiders. The focus is on access regulation to network facilities, while retail market is totally unregulated.

The broadband services are sold by both operators to end-users at a fixed subscription fee independent of actual usage and time connected. Hence firms face downward sloping demand curves. Services provided by the two firms are perfect

substitutes. Considering the fact that firms face capacity constraints in the regional and the global backbones, the model assumes that the retailers compete à la Cournot and the quantity they sell is interpreted as the number of subscriptions. Furthermore, it is assumed a constant access pricing rule. Finally, as in Cambini and Silvestri (2012), it is also assumed that the regulator has limited ability to make credible commitment before the incumbent invests. The regulator can commit to a certain regulatory regime, but not to the specific level of the access charge.[7] Therefore when access regulation exists, the charges are contracted ex post by the regulator and the firms.

Here is the timing structure of the model:

Stage 1: The co-investing firms choose the investment extent;

Stage 2: Once the investment in the new network is deployed, with joint-venture, the firms set the level of insiders' fee to be paid to access the NGN for the provision of broadband services;

Stage 3: The firms compete à la Cournot in the retail market.

Notice that in case of basic investment sharing (B), there is no Stage 2, because the access price to the NGN is set at zero.

Demand Side

Consumers have unit demand. Their valuation of a firm's service is divided into two parts: one is for the basic broadband services and the other is for the value-added services running on NGN (Foros (2004) and Cambini and Silvestri (2012)). Therefore a representative consumer's valuation of firm's service is given by:

$$v + \beta m$$

Here v is interpreted as the consumer's willingness to pay for the basic service without new technology and is assumed to be uniformly distributed in $(-\infty, a]$. Neg-

[7]The literature is divided over the possibility of regulatory commitment. For example, Foros (2004) assumes that regulatory commitment is always absent, similarly to the paper by Brito et al. (2010), where the adoption of a two-part tariff can partially mitigate the regulatory commitment problem. In contrast, the regulator's capability of credible commitment is present in Nitsche and Wiethaus (2011).

ative values of v are allowed in order to avoid corner solutions where all consumers enter the market. β describes the consumers willingness to pay for the chance to get value-added services thanks to the enhanced quality of the NGN network. It is assumed that $\beta \in [0, 1]$, depending on the firms' ability to transform input into output. Similarly to Foros (2004), it is assumed that consumers are heterogenous in their willingness to pay for broadband connectivity, but they are homogenous in their valuation for the improved network quality. The term m represents the extent of the NGN investment. In this model, a higher investment increases the quality of the services and therefore pushes market demand outwards.

The subscription fee charged by firm i is p_i. A representative consumer buys from firm i other than firm j ($j = 1, 2$ and $j \neq i$) if the following conditions are satisfied:

$$v + \beta m_i - p_i > v + \beta m_j - p_j$$

If both firms are active, the quality-adjusted prices should be the same:

$$p_i - \beta m_i = p_j - \beta m_j = P$$

Denote the incumbent with subscript 1 and the OLO with subscript 2, then notice that m_2 can be either equal to m_1 if both firms use the NGN, i.e. $m_1 = m_2 = m$, or it can be equal to zero if the OLO uses the copper network, i.e. $m_2 = 0$.

Consumers whose willingness to pay for the basic service v is no lower than the price P enter the market, so there are $a - P$ active consumers. The total quantity provided by firms is $Q = q_1 + q_2$, so $Q = a - P$. Thus the inverse demand functions faced by the firms are:

$$\begin{cases} p_1 = a + \beta m_1 - q_1 - q_2 \\ p_2 = a + \beta m_2 - q_1 - q_2 \end{cases}$$

Supply side

It is assumed that the marginal cost is constant and equal to c for NGN-based services, independent of the investment level. It is reasonable to believe that $a > c$, since it is a necessary condition for the firms to be active in the NGN market. The

investment cost is assumed to be a quadratic cost given by $C(m) = m^2\phi/2$. Here ϕ is a positive cost parameter, which denotes the scale of the investment cost. It is assumed that $\frac{d}{dm}C \geq 0$ and $\frac{d^2}{dm^2}C > 0$. For simplicity, all other costs are assumed to be the same for both firms and normalized to zero.

In order for the Second Order Conditions (SOCs) to be verified in every of the cases analysed in the paper, the scale of the investment cost, ϕ, needs to be much higher than the willingness to pay for the value-added services, β, which is somewhat confirmed by the real situation in the market. Such condition is expressed in the following assumption:

Assumption 2.1.

$$\phi > \beta^2$$

The fee for the use of the NGN is denoted with r^l, where the superscript $l = B, JV$ corresponds to the cases of basic investment sharing and joint-venture, respectively. In case of basic investment sharing, $r^B = 0$ by assumption. Finally, let r_r be the "regulated" fee.

Following Bresnahan and Salop (1986), the individual aggregate profits of the two firms, including their respective participation to the co-investment agreement, are the following:

$$\begin{cases} \pi_1^l = (p_1^l - r^l)q_1^l + \alpha((r^l - c)(q_1^l + q_2^l) - m_1^2\phi/2) \\ \pi_2^l = (p_2^l - r^l)q_2^l + (1-\alpha)((r^l - c)(q_1^l + q_2^l) - m_2^2\phi/2) \end{cases} \tag{2.1}$$

The parameter $\alpha \in (0, 1)$ represents the way in which the investment cost is shared between the two firms, or otherwise said, the fraction of the joint venture owned by a firm. Notice that the first term of the expression represents a firm's individual profit, while the second term represents a firm's share of the co-investment consortium's profits.

The following assumption is made for the model.

Assumption 2.2. $r_r \geq c$

Upstream sales of access to the NGN must yield a non-negative price cost margin, if the NGN access market is regulated.

Social Welfare

The social welfare function is:

$$W = \frac{a + \beta m_1 - p_1}{2} q_1 + \frac{a + \beta m_2 - p_2}{2} q_2 + \pi_1 + \pi_2 - m^2 \phi / 2$$

In what follows different scenarios are analysed: basic investment sharing (B) and joint-venture (JV), respectively. Before this, the analysis of scenario with no sharing agreement (N) is presented. This case is considered as an outside option and it is can be considered as a benchmark, where the incumbent invests alone and then gives access to the NGN at regulated conditions.

2.2 Outside option: No sharing agreement

Consider the case when the two firms do not make any sharing agreement, which constitutes the outside option to the co-investment alternative.

Stage 3: Retail market competition

The incumbent invests in the NGN on a stand-alone basis, since there is no co-investment agreement (N). It is assumed that it is then forced to provide the OLO with access to the NGN at regulated conditions r_r.[8]

The profit functions are the following:

$$\begin{aligned} \pi_1^N &= (p_1^N - c) q_1 + (r_r - c) q_2^N - (m^N)^2 \phi / 2 \\ \pi_2^N &= p_2^N q_2^N - r_r q_2^N \end{aligned}$$

The profit maximisation problem yields the following equilibrium quantities in the retail market:

$$\begin{cases} q_1^{N*} = \frac{a - 2c + \beta m^N + r_r}{3} \\ q_2^{N*} = \frac{a + c + \beta m^N - 2 r_r}{3} \end{cases}$$

[8]The case where the incumbent chooses the access price to the NGN is not considered, since it has been already studied in a companion paper to this one, Cambini and Silvestri (2012). In that paper, it is shown that, when the two firms have equal ability in offering value-added services, the incumbent always prefers to exclude the OLO from the NGN, like in Foros (2004).

Stage 2: Choice of access price to the NGN

The regulator sets the access charge that the OLO has to pay in case there was no co-investment agreement. The welfare function writes as below:

$$W^N = \frac{(q_1^{N*} + q_2^{N*})^2}{2} + (q_1^{N*})^2 + r_r q_2^{N*} - (m^N)^2\phi/2 + (q_2^{N*})^2$$

The first-order condition with respect to r_r gives the access price as:

$$r_r^* = 2c - a - \beta m^N$$

The access price margin, $r_r^* - c = c - a - \beta m^N$, is negative, since $a - c > 0$ is a necessary condition for a broadband market to exist and βm^N is assumed to be non negative. Therefore, to respect condition (2.2), it is imposed:

$$r_r^* = c$$

Stage 1: Choice of investment's extent

In this case, the incumbent chooses the following level of NGN deployment:

$$m^{N*} = \frac{2\beta(a-c)}{9\phi - 2\beta^2}$$

In the three-firms case, the analysis is analogous, but instead of having one incumbent and one access seeking firm, there are one incumbent and two access seeking firms. The regulated access price is the same and the equilibrium choice of investment by the incumbent changes as below:

$$m^{N*} = \frac{\beta(a-c)}{8\phi - \beta^2}$$

2.3 Basic Investment Sharing

In the basic investment sharing case (B), the incumbent and the OLO share *only* the cost of the investment and then each of them is entitled to use the NGN without

having to make any side payment.

Stage 3: Retail market competition

Since the firms are symmetric, for the ease of exposition it is assumed henceforth that $\alpha = 1/2$.[9] In this case firms do not pay each other any internal transfer for using the NGN, hence $r^B = 0$. Firm i's profits, with $i, j = 1, 2$ and $i \neq j$, can be written as:

$$\pi_i^B = (p_i^B - c)q_i^B - (m^B)^2\phi/4$$

The first-order conditions give the following individual equilibrium quantities in the retail market:

$$\begin{cases} q_1^B = \frac{a+\beta m^B - c}{3} \\ q_2^B = \frac{a+\beta m^B - c}{3} \end{cases} \tag{2.2}$$

Stage 1: Joint choice of investment's extent

Given the equilibrium quantities, firms choose directly the level of investment. The objective function is constituted by the sum of the two firms' individual aggregate profits, once considered the equilibrium quantities found above.

$$max_{m^B}\pi_{12}^B = \frac{2\left(a + \beta m^B - c\right)^2}{9} - (m^B)^2\phi/2$$

[9]Notice that also in the French regulation, to which this model is in many ways inspired, common costs must be shared equally by the members of the co-investment agreement (Arcep (2009)). However, it is worth noting that this is only one - and obviously the easiest - way of the possible rules of investment sharing. There may be other sharing rules that can cause more market distortions. In fact, according to the BEREC (2012) report on co-investment, one of the biggest risks of this type of agreements is the fact that firms transform fixed costs into marginal costs by making their contribution to the fixed cost depend on the quantities they sell. By this way they are able to increase their perceived marginal cost, thus decreasing competition intensity. The authors thank one Referee for pointing this out.

The level of investment according to the first-order condition is:[10]

$$m^{B*} = \frac{4\beta(a-c)}{9\phi - 4\beta^2}$$

2.4 Joint-venture with Internal Transfer

In the joint-venture case (JV), the members of the consortium agree to deploy NGN jointly and then decide upon the side-payment for the use of the network. Such insiders' reciprocal fee is set so as to maximise joint profits. In practice, this case exemplifies the situation where members of the agreement build or manage parts of NGN in different geographical areas, or it simply represents a sort of payment clearing system into which each firm using the NGN pays a fee each time it uses the NGN and then the total amounts of internal transfers are redistributed to each member of the co-investment agreement. Since it is assumed $\alpha = 1/2$, firm i's profits, with $i, j = 1, 2$ and $i \neq j$, can be written as:

$$\pi_i^{JV} = (p_i^{JV} - r^{JV})q_i^{JV} + 1/2((r^{JV} - c)(q_i^{JV} + q_j^{JV}) - (m^{JV})^2\phi/2)$$

Stage 3 equilibrium is similar to what has been reported in equation (2.2) for the B case, but with $r^{JV} \geq 0$. It results: $q_1^{JV} = q_2^{JV} = \frac{a+\beta m^{JV} - (r^{JV}+c)/2}{3}$.

Stage 2: Choice of NGN internal fee

The incumbent and the OLO decide cooperatively what will be the fee to access the NGN, by choosing the level that maximises their collective profits:

$$max_{r^{JV}} \pi_{12}^{JV} = \frac{(2(a + \beta m^{JV}) - (r^{JV} + c))(a + \beta m^{JV} + r^{JV} - 2c)}{9} - (m^{JV})^2\phi/2$$

The optimal level of NGN internal transfer for the members of the joint-venture

[10] It is also possible to analyse the choice of whether the firms would spontaneously cooperate in a joint NGN investment, considering their outside option profits reported in Section 2.2. Results show that, for $\alpha = 1/2$, both the incumbent and the OLO prefer a basic investment sharing agreement unambiguously, when the alternative is the incumbent investing alone and then giving access to the NGN at marginal cost level. This result depends on the fact that investment is larger in the scenario B than in the outside option case, expanding total demand. Results are available upon request.

agreement is then:

$$r^{JV*} = \frac{a + c + \beta m^{JV}}{2}$$

It is interesting to note that, when the joint venture agreement involves all the market operators and they decide the NGN insiders' fee internally, they set a positive fee. Knowing that they face no other competitors in the retail market, the two firms use the NGN internal fee to soften competition downstream and increase their profits. This is one of the potential risks connected to the presence of co-investment agreements for the NGN deployment (BEREC (2012)).

Stage 1: Joint choice of investment's extent

The optimal investment level in the JV case corresponds to the level of m that maximises $\pi_{12}^{JV}(r^{JV*})$, as given by the following condition:[11]

$$m^{JV*} = \frac{\beta(a-c)}{2\phi - \beta^2}$$

2.5 Comparison of results under basic investment sharing, joint-venture and incumbent stand-alone investment

In this Section, a comparison between the results in terms of industry output and investment levels in case of three above mentioned scenarios is reported.

Lemma 1. *For a given investment extent m and under the assumptions $r_r \geq c$ and $\alpha = 1/2$, industry output satisfies*

$$Q^B(m) > Q^N(m) > Q^{JV}(m)$$

Proof. See Appendix A.1.1. □

[11] Even in this case, the incentives to undertake a JV agreement has been analyzed comparing the profit in the joint-venture case with the profit in case of no cooperative agreement. It turns out the both the incumbent and the OLO would prefer to make the joint-venture agreement JV with respect to the outside option N unambiguously. This is not surprising as in the joint-venture case the two firms set the level of access charge and investment extent in order to soften retail competition. Results are available upon request.

Basic investment sharing yields a higher level of competition than the outside option scenario, where the incumbent firm invests and then is mandated to give access at cost-based conditions. The reason behind the inequality that follows is that in the joint venture type of agreement, the two firms have the incentive to set a positive reciprocal fee to dampen competition downstream.

As regards to the investment levels, the following statement is derived:

Lemma 2. *Under the assumption $r_r \geq c$ and $\alpha = 1/2$, the equilibrium level of investment extent m satisfies*

$$m^{JV*} > m^{B*} > m^{N*}$$

Proof. See Appendix A.1.2. □

This result can be analysed in two steps. First, both co-investment agreements internalise the positive effect of investment on the OLO's profit whereas, in absence of agreement, the incumbent only considers the effect on its own profit. Second, when firms are left free to choose the insiders NGN usage fee, there is a further increase of the investment incentive, because firms gain higher profits thanks to the softening of competition downstream obtained by setting a positive reciprocal fee. Moreover, the level of investment in basic investment scenario is higher than in the no investment sharing case due to the depriving effect of regulation (see Appendix A.1.2).

It is now possible to make a comparison, in terms of consumer surplus CS, and welfare, W, among the three different scenarios, i.e. B, JV, N. Results are summed up in the following Proposition:

Proposition 1. *Under the assumption $r_r \geq c$ and $\alpha = 1/2$, the equilibrium levels of consumer surplus and welfare satisfy the following conditions:*

$$\begin{aligned} &CS^B > CS^N \text{ and } W^B > W^N \\ &CS^{JV} > CS^N \text{ and } W^{JV} > W^N \text{ unambiguously only if } \phi < \frac{4\beta^2}{3} \\ &CS^B > CS^{JV} \text{ and } W^B > W^{JV} \end{aligned}$$

Proof. See Appendix A.1.3. □

There is a clear ranking between basic investment sharing and no sharing. The former performs better than the latter in terms of consumer surplus and welfare. As it can be seen from Lemmas (1) and (2), basic investment sharing ensures a higher level of downstream competition than the no sharing alternative scenario and it gives firms higher investment incentives. Since the investment in NGN increases the demand, a positive effect on consumer surplus and welfare emerges. These results together determine the superiority of basic investment sharing with respect to no sharing from a social perspective, confirming previous results in Nitsche and Wiethaus (2011) and Cambini and Silvestri (2012). Turning to the joint-venture case, from Lemmas (1) and (2), it results that joint-venture implies the lowest level of downstream competition and the highest level of investment. Since these two results go in opposite directions in terms of both consumer surplus and welfare, it is rather plausible not to obtain clear results. In particular, if the investment cost parameter ϕ is not too high, or otherwise stated, if the return from the NGN investment β is high enough, i.e. if $\phi < 4\beta^2/3$, joint-venture performs better both in terms of consumer surplus and welfare than no sharing. The reason is that, even though the level of competition is weaker with joint-venture, due to the effect of the positive insiders' NGN charge, the higher investment incentive may overcompensate for the reduction in competition, when the investment conditions (investment cost and return) are favorable enough. Finally, consumer surplus and welfare are higher in the basic investment scenario than in the joint-venture case.

3 Investment Sharing with an outsider firm

The regulatory framework for pre-existing networks is designed to avoid that the conditions for network access and usage are discriminatory among different operators. When the issue is the construction of a new network though, there must be a special reward for the firm(s) who build the network, otherwise it would not be worthwhile to incur in the investment costs in the first place. For this reason, for example, in the French regulation (Arcep, 2009), outsiders to the sharing agreement can either ask to join the agreement by paying a part of the incurred investment cost and then using the NGN at the same conditions as the initial members of the consortium, or they can stay out of the agreement and pay an access charge inclusive of a premium. In this model, the case where the outsider can ask for access to

the NGN by paying an access charge that can be chosen by the insiders or by the regulator is analysed.

3.1 Basic Investment Sharing with an outsider firm

Consider an outsider firm, denoted with the subindex 3, which enters the retail market once the incumbent and the OLO have already made a basic investment sharing agreement and invested in the NGN roll-out. It is assumed that the late entry of the outsider firm is predictable and so the two co-investing firms take their decisions knowing that the final competition will include another firm. This common knowledge assumption is reasonable since the entry of a new firm in markets such as the telecommunications market is often pre-announced through business news and corporate publicity, ahead in time with respect to the actual entry. Moreover, it is plausible that the co-investing firms take into consideration the potential entry of other firms, and make consequent decisions.

Notice that the presence of the late entrant adds the outsiders access charge decision to the game. The timing structure is now:

Stage 1: The co-investing firms choose the investment extent;

Stage 2: Once the investment in the new network is deployed: the firms set the NGN insiders' fee, with joint-venture; the firms (or the regulator) set the outsider's NGN access price, with either basic investment sharing or joint-venture investment sharing;

Stage 3: The three firms compete à la Cournot in the retail market.

Stage 3: Retail market competition

The late entrant is entitled to ask for access to the newly built NGN, by paying an access price $r^{B,L}$, where L denotes the case with late entrant. The incoming revenues from sales of access to the late entrant are then shared by the two co-investing firms according to firm's contribution to the investment cost, α assumed equal to 1/2. A co-investment agreement may in fact include an exclusivity clause for the use of the NGN in favour of the members of the agreement, but such clause would very unlikely be approved by a competition authority (BEREC (2012)). However, access conditions might be such as to exclude the late entrant from the use of the NGN, if

the co-investing firms were to choose freely the access price level, as it will be shown later in the analysis.

The profit functions become:

$$\begin{aligned}\pi_1^B =&(p_1^B - c)q_1^B + 1/2((r^{B,L} - c)q_3^B - (m^B)^2\phi/2)\\ \pi_2^B =&(p_2^B - c)q_2^B + 1/2((r^{B,L} - c)q_3^B - (m^B)^2\phi/2)\\ \pi_3^B =&(p_3^B - r^{B,L})q_3^B\end{aligned}$$

Assuming that the outsider uses the NGN, the first-order conditions give the following equilibrium quantities in the retail market:

$$\begin{cases} q_1^B = q_2^B = \frac{a-2c+\beta m^B + r^{B,L}}{4} \\ q_3^B = \frac{a+2c+\beta m^B - 3r^{B,L}}{4} \end{cases}$$

Stage 2: Choice of NGN access price

In the basic investment sharing case, only the outsider's NGN access price has to be chosen. Two different cases here are analysed: the co-investing firms choose the outsider's access price, $r^{B,L}$; the regulator chooses the outsider's access price, $r_r^{B,L}$, where the subscript r denotes the choice of the regulator.[12] The outsider firm asks access to the NGN and then, depending on the access conditions, decides whether to use the NGN or to use the pre-existing copper network. It is assumed that the copper network access is regulated at marginal cost, $r_c = c_c$, where the subscript c indicates the old copper network and c_c is the marginal cost of using the copper network. This assumption is plausible given the current regulation for legacy networks in most European countries, where the main concern is ensuring competition, and the fact that investments in copper network have long been covered, on top of having often been made by the state at the time when telecommunication companies were publicly owned. The marginal cost of network operation for the copper network

[12]It is relevant to look at this case because, if firms are left free to choose the outsider's access price level, they might exclude the outsider firm from the NGN market. The regulator instead may be interested to ensure that the migration to the new and more efficient technology is faster, also to avoid the social cost of a network duplication and eventually allow the switch off of the copper network.

can be higher or at most equal to the marginal cost of NGN operations, $c_c \geq c$. For the sake of simplicity, in the following, it is assumed that $c_c = c$, which does not change the insight of the analysis, but makes the exposition clearer. Note also that, when using the copper network, the outsider firm is in a disadvantage with respect to the insiders since it provides lower quality broadband services only. The outsider's decision to enter the broadband market using the "old" copper network is therefore negatively affected by the investment decision of insiders on the "new" NGN network: the more the insiders invest in new services, the less attractive becomes the old ones. Hence, notwithstanding that access charge are regulated at cost, the outsider may still be excluded from the market even when using the copper network.

When the insiders choose the outsider's access price, in the basic investment sharing framework, the internal NGN usage fee becomes:[13]

$$r^{B,L} = \begin{cases} \frac{2(a+\beta m^B)+3c}{5} & \text{if } \phi < \frac{9\beta^2}{5} \\ c + \beta m^B & \text{otherwise} \end{cases}$$

In the first case, the insiders exclude the late entrant from the NGN. They find it convenient to do so if the investment cost parameter ϕ is not too high with respect to the return from the investment β. If the outsider firm gains no access to the NGN, indeed, the co-investing firms benefit from the NGN exclusively through the retail sales of the value-added services, because they still face the competition of the outsider firm on the basic services, which are possible to supply via copper network. If such benefits are high enough, because the demand is particularly responsive to the offer of value-added services, than the co-investing firms find it better to exclude the late entrant. If, instead, the investment cost parameter ϕ is high enough with respect to the return from the investment β, , i.e. $\phi > 9\beta^2/5$, the increase in profits obtainable thanks to the sale of value-added services on the NGN is relatively lower, so the co-investing firms are interested in gaining some profits from the upstream sales of access to the NGN. In this case, the co-investing firms set a NGN access charge which is higher than marginal cost, but that keeps the late entrant active in the NGN market.

[13]See Appendix A.1.4.

Stage 1: Joint choice of investment's extent

In the case when the co-investing firms choose the outsider's NGN access price, two different equilibrium levels of investment emerge, depending on the parameters. The joint profits maximisation by the co-investing firms yield the following equilibrium investment levels:

$$m^{B*} = \begin{cases} \frac{4\beta(a-c)}{9\phi-4\beta^2} & \text{if } \phi < \frac{9\beta^2}{5} \\ \frac{3\beta(a-c)}{4\phi} & \text{otherwise} \end{cases}$$

In the first equilibrium, the outsider is always excluded from both the NGN and the copper networks. The exclusion depends on a strategic use of investment, but also due to a high consumers' willingness to pay for NGN services, β, that makes the outsider unable to remain active in the market.[14] The investment equilibrium level in this case is equal to the equilibrium when only the insiders are active and share the investment costs. In the second equilibrium, the outsider is not excluded from the NGN market and compete with the insiders.

3.1.1 Regulator's choice of the outsider's access fee

The optimal regulated access price is given by maximizing welfare and it results:

$$r_r^{B,L} = 2c - a - \beta m^B$$

As in the two-firms case previously analysed, the access price margin given by the regulated access charge is negative, because $a > c$ and $\beta > 0$ by assumption, and m cannot be negative, because it represents the investment level. Therefore, by assumption (2.2), it results:

$$r_r^{B,L} = c$$

[14] In order to remain active in the broadband market using at least the "old" copper network the consumer's willingness to pay for NGN services has to be very low relatively to the cost of the infrastructure, i.e. $\phi > 2\beta^2$. Instead, when using the NGN, the condition for the outisder to be active in the market is $\phi > 3\beta^2/2$ which is always satisfied when $\phi > 9\beta^2/5$.

This leads to the following equilibrium investment level:

$$m^{r,B} = \frac{\beta(a-c)}{4\phi - \beta^2}$$

3.2 Joint-venture with an outsider firm

Let's analyse the case of joint-venture when there is one outsider firm in the market. In this scenario, initially the incumbent and one OLO decide to make an agreement for the joint roll-out of the NGN. After the investment deployment, the co-investing firms set the level of the internal transfer for the use of the newly built NGN among the members of the agreement, $r_I^{JV,L}$, where the subscript I indicates "insiders" and L indicates the case with an outsider firm. Two cases for the outsiders' access charge are analysed: in one case - $r_o^{JV,L}$, where the subscript o indicates "outsider" - the co-investing firms also set the outsider's NGN access price; in the other case, the regulator sets the NGN access price for both outsiders and insiders. Finally, there is competition in the retail market.

Stage 3: Retail market competition

Once the co-investing firms start offering services in the final market, using the newly built NGN, another firm enters the market and asks for access to the NGN. The following are the profits of the three firms assuming that the outsider firm obtains access to the NGN:

$$\begin{aligned}
\pi_1^{JV} =& (p_1^{JV} - r_I^{JV,L})q_1^{JV} + 1/2((r_I^{JV,L} - c)(q_1^{JV} + q_2^{JV}) + (r_o^{JV,L} - c)q_3^{JV} - (m^{JV})^2\phi/2) \\
\pi_2^{JV} =& (p_2^{JV} - r_I^{JV,L})q_2^{JV} + 1/2((r_I^{JV,L} - c)(q_1^{JV} + q_2^{JV}) + (r_o^{JV,L} - c)q_3^{JV} - (m^{JV})^2\phi/2) \\
\pi_3^{JV} =& (p_3^{JV} - r_o^{JV,L})q_3^{JV}
\end{aligned}$$

The first-order conditions give the following equilibrium quantities in the retail market:

$$\begin{cases}
q_1^{JV} = \frac{a-c+\beta m^{JV} - r_I^{JV,L} + r_o^{JV,L}}{4} \\
q_2^{JV} = \frac{a-c+\beta m^{JV} - r_I^{JV,L} + r_o^{JV,L}}{4} \\
q_3^{JV} = \frac{a+c+\beta m^{JV} + r_I^{JV,L} - 3r_o^{JV,L}}{4}
\end{cases}$$

Stage 2: Choice of NGN access price

In the joint-venture case, the co-investing firms choose both the insiders' internal fee to use the NGN, $r_I^{JV,L}$, and the outsider's access price, $r_o^{JV,L}$. Similarly to the basic investment sharing case shown in the previous Section, the alternative to the NGN for the outsider firm is the regulated copper network.

In the case when the insiders choose the outsider's access price, with joint-venture, the outsider's access charge and the insider's NGN fee are respectively:[15]

$$r_o^{JV,L} = \begin{cases} \frac{a+c+\beta m^{JV}}{2} & \text{if } \phi < \frac{8\beta^2}{5} \\ c + \beta m^{JV} & \text{otherwise} \end{cases} \tag{3.1}$$

$$r_I^{JV,L} = \begin{cases} c & \text{if } \phi < \frac{8\beta^2}{5} \\ c + \beta m^{JV} & \text{otherwise} \end{cases} \tag{3.2}$$

If the investment cost parameter is not too high with respect to the return of the investment in terms of demand increase, the co-investing firms prefer to set the outsider's access price at monopoly level and exclude the outsider firm from the NGN. In this case the co-investing firms set the insider's NGN fee at marginal cost level in order to be most competitive against the new entrant in the sale of the basic services, knowing that they face no competition in the sale of the value-added services via NGN. In this scenario, competition downstream is high but the market technological developments are not available to all firms. If the investment cost is high enough compared to the return from the investment though, the co-investing firms find it convenient to set the outsider's access charge at the level that makes using the NGN or the copper network indifferent for the outsider firm, in which case it is assumed that the outsider firm uses the NGN (as in Cambini and Silvestri (2012)). When they do so, the insider's NGN fee is equal to the outsider's access charge.

Stage 1: Joint choice of investment's extent

[15] See Appendix A.1.5.

When the co-investing firms choose both insider's and outsider's access charge to the NGN, the following are the equilibrium investment levels:

$$m^{JV*} = \begin{cases} \frac{\beta(a-c)}{2\phi-\beta^2} & \text{if } \phi < \frac{8\beta^2}{5} \\ \frac{3\beta(a-c)}{4\phi} & \text{otherwise} \end{cases}$$

As before, in the first equilibrium, the outsider is completely excluded from the broadband market and the exclusion depends both on a strategic use of investment, but also on the relatively high consumers' willingness to pay for NGN services, β, that makes the outsider unable to remain active in the market providing only "low quality" broadband services on the copper network. The second equilibrium represents the optimal investment level when the outsider is not excluded from the NGN market.[16]

3.2.1 Regulator's choice of uniform NGN access fee

The regulator here can intervene by choosing a uniform level of NGN access charge that all firms using the NGN must pay without discrimination. It is interesting to analyse the implications of the regulator's intervention since, as seen above, there might be problems of foreclosure from the NGN of latecomers in this market.

Stage 2: Regulator's choice of uniform NGN access fee

Considering assumption (2.2), the NGN access charge chosen by the regulator - which is denoted by r_r where the superscript r stands for regulation - is equal to:

$$r_r^{JV,L} = c$$

Stage 1: Joint choice of investment's extent

When the regulator chooses a uniform access fee to the NGN, the co-investing

[16]The threshold for the outsider to remain active in the broadband market using the "old" copper network is always $\phi > 2\beta^2$. As before, the threshold for the outsider to be active in the NGN market is $\phi > \beta^2$ which is always satisfied by Assumption 2.1.

firms choose the following equilibrium investment level:

$$m^{r,JV} = \frac{\beta(a-c)}{4\phi - \beta^2}$$

Note that, in case of regulation, the optimal investment level in presence of a joint venture is exactly the same as in the basic investment scenario.

3.3 Comparison with an outsider firm

This section presents a comparison between the results in case of and in absence of regulation in each of the cases previously analysed. In more details, the idea is to compare the basic investment scenario B when the co-investing firms are left free to choose the level of the outsider's access charge with the case where the access charge for the outsider is set by a regulator equal to marginal cost c. Similarly, the joint investment case is compared with the case where access fee for both the insiders and outsider is uniformily set by the regulator equal to c. The following proposition sums up the main results:

Proposition 2. *Under the assumptions $r_r \geq c$ and $\alpha = 1/2$:*

- *Retail competition is higher when the NGN access price is regulated than when there is a joint venture investment sharing, as well as when there is basic investment sharing;*
- *The equilibrium investment level is higher when the co-investing firms are left free to choose the NGN access prices.*

Proof. See Appendix A.1.6. □

This result is representative of the trade-off between static and dynamic efficiency. Co-investing agreements call for some sort of regulation in order to avoid its potential effect of dampening competition downstream. However, co-investing agreements also boost firms' investment incentives and therefore consumer surplus especially in presence of unregulated sharing agreements. This implies that, from a policy perspective, if it is socially relevant to speed up the switch-off of the copper network, then the regulator should not regulate access to the NGN in presence of

investment sharing when the agreement does not involve all the market operators, even though the latecomer might be excluded from the NGN market.

Comparing the results in terms of industry output and investment levels in case of basic sharing, joint-venture and no sharing case when there are two co-investing firms and one late entrant in the NGN market, it is possible to state the following:

Lemma 3. *For a given investment extent m and under the assumptions $r_r \geq c$ and $\alpha = 1/2$, industry output satisfies*

$$\begin{aligned} Q^B(m) &> Q^{JV}(m) \\ Q^N(m) &> Q^B(m) \\ Q^N(m) &> Q^{JV}(m) \end{aligned}$$

Proof. See Appendix A.1.6. □

The first inequality indicates that basic investment sharing yields a higher level of competition than joint-venture. The following inequality shows that, compared to the alternative scenario with a stand-alone investment by the incumbent and mandated access at marginal cost for the two OLOs, basic investment sharing yields lower quantity. Similarly, joint-venture gives a lower level of competition for any given investment level, than no investment sharing. When there is one firm outside of the sharing agreement, the co-investing firms lower the insiders' internal transfer, and this, in turn, results in higher competition downstream with respect to the case where the co-investing firms covered the whole retail market and exclusion emerges. In terms of policy recommendation, this result suggests that, although sharing the cost speeds the NGN deployment up, competition may be dampened. Moreover, exclusion of outsiders is more likely to happen when only a sub set of firms active in the market participate to the agreement. As suggested by the BEREC (2012) report, a trade-off must be found between number of firms active in the market and number of co-investing firms, in order to minimise the risk of anticompetitive behaviour.

As regards to the investment levels, the following statement is derived:

Lemma 4. *Under the assumption $r_r \geq c$ and $\alpha = 1/2$, the equilibrium level of investment extent m satisfies*

$$m^{JV*} > m^{B*} > m^{N*}$$

Proof. See Appendix A.1.6. □

Similarly to the case with only two firms, investment sharing yields higher investment incentives, with respect to the case where the incumbent invests alone and then gives access to the NGN at regulated conditions, for a large range of parameters. Also the comparison between basic investment sharing and joint-venture provides similar results: investments in the joint venture scenario are always higher than investments in the basic investment case both when insiders exclude the late entrant from the broadband market and when this latter is active at retail level. When the co-investing firms exclude the late entrant from the NGN, they compete fiercely on basic services while benefitting from the sales of the value-added services exclusively. When the late entrant is not excluded, it benefits of a spillover effect from the chance to exploit the NGN, the co-investing firms tend to invest relatively less, even though they get part of the late entrant's benefits via the NGN access price, which is higher than marginal cost.

In terms of consumer and social welfare, CS and W, the following statement holds:

Proposition 3. *Under the assumption $r_r \geq c$ and $\alpha = 1/2$, the equilibrium levels of consumer and social welfare satisfy*

$$CS^B > CS^{JV} > CS^N$$

$$W^B, W^{JV} > W^N$$

$$W^B > W^{JV} \text{ if } \phi < 8\beta^2/5 \text{ and } \phi > 9\beta^2/5$$
$$W^B < W^{JV} \text{ otherwise}$$

Proof. See Appendix A.1.6. □

When one late entrant shows up in the market, the ranking of consumer and social welfare changes with respect to the case with only the two co-investing firms. The superiority of the investment sharing solutions compared to the outside option, where the incumbent invests on a stand-alone basis and then gives access to the OLOs at marginal cost, is reinforced, no matter the contractual form of investment sharing considered here, and also in cases of exclusion of the late entrant from the broadband market. Moreover, the comparison between joint-venture and basic investment sharing reveals that basic investment sharing yields a higher consumer surplus, while joint-venture investment sharing guarantees higher investments. The results are less clear cut when the two contractual forms are compared in terms of total welfare. Depending on the value of the investment cost parameter and the shift in demand caused by the investment, basic investment sharing yields a higher total welfare than joint-venture investment sharing both when there is exclusion or inclusion under both scenarios. When, instead, there is exclusion with basic investment sharing and inclusion with joint-venture investment sharing, i.e. $8\beta^2/5 < \phi < 9\beta^2/5$, the joint-venture option yields a higher total welfare.

4 Conclusion

This paper develops a model of competition between an incumbent firm and an OLO in the broadband market, where the incumbent has an investment option to build a NGN and it can do so by making a sharing agreement with the OLO, or alone. Differently from previous theoretical research, this paper discusses two different kinds of sharing contractual forms — basic investment sharing, where no side-payment is given for the use of the NGN between co-investors, and joint-venture, where an insiders' internal transfer is set by the co-investing firms — comparing them with the scenario in which the incumbent invests on a stand-alone basis. Then, the model is extended considering the entry of an outsider firm, with option to ask access to the NGN. The final purpose of the paper is to analyse how policy settings, particularly regarding network access rules, affect the firms' investment choice.

Consistent with the result in Cambini and Silvestri (2012), results show that the presence of a basic investment sharing agreement positively affects competition and it also gives fairly high investment incentives compared to the no risk sharing alternative, but also to the joint-venture case. For these reasons, the paper shows

that basic investment sharing is the preferable option in most cases. As regards to the joint-venture case, when the agreement is made by all the firms present in the market, it is more likely to dampen competition downstream so much that, although the investment incentives are stronger, the results in terms of consumer surplus and social welfare tend to favour basic investment sharing.

As a policy recommendation, drawn by the comparison between the case with two firms and the case with the addition of an outsider, it results that investment sharing can potentially be beneficial in terms of competition and investments, but the concerns shown by the authorities related to the inherent form of such agreements are not void. The number of firms involved matters and so does the choice of the NGN access price, for insiders and outsiders of the sharing agreement. Although eventually the regulators' objective is having no more network duplication, it might not be an optimal strategy for a start to have all firms in the market involved in a sharing agreement, unless the insiders NGN usage transfer is constrained at zero, like in the basic investment sharing case. Even when the presence of firms outside of the agreement forces insiders to compete more fiercely, there might be a concern with the potential exclusion of outsiders from the ultra-fast broadband market. In this framework, NGN access regulation has a positive effect on competition, but it also largely reduces investment incentives. If the urgency of the regulator is to ensure that, once it is deployed, the highest possible number of firms can use the NGN, then this result says that ex-ante regulation is necessary to avoid foreclosure, even though it reduces investment incentives. On the contrary, if it is socially beneficial to have a fast and a wider deployment of an NGN infrastructure, then ex ante intervention should be at least partially relaxed. Many regulatory authorities have indeed introduced ex ante rules for NGN (such as obligations for granting access to dark fiber or local loop unbundling to fiber) but the economic conditions of wholesale services are much more debated, with several countries imposing above-cost access prices to both consider static and dynamic goals (Cullen International, 2012).

The framework used in this paper abstracts from the presence of demand uncertainty in order to shed light on the contractual mechanisms of the investment sharing agreements, which has not yet been examined satisfactorily by the literature. One extension to this paper could surely integrate the context with uncertainty, making with any probability investment and welfare results lower in absolute values in all cases, as it is found in a companion paper to this one (Cambini and Silvestri (2012)).

Indeed, uncertainty is probably one of the most relevant issue influencing investment incentives. Another interesting extension might be introducing an asymmetry between firms participating to the co-investment agreement with and without internal transfers. Finally, other alternative forms of sharing agreements could be analysed, such as one in which the outsider can pay a share if the investment cost and be made part of the co-investment consortium even after the NGN deployment.

A Appendix

A.1 Proofs

A.1.1 Proof of Lemma 1

The total industry output, for any level of investment, is $Q^l(m)$, with $l = B, JV, N$.

$$\begin{aligned} Q^N(m) =& \frac{2(a + \beta m^N - c)}{3} \\ Q^B(m) =& \frac{2(a + \beta m^B - c)}{3} \\ Q^{JV}(m) =& \frac{(a + \beta m^{JV}) - c}{2} \end{aligned}$$

From these equations, the following relationship is obtained:

$$Q^B(m) \geq \ Q^N(m) > Q^{JV}(m)$$

A.1.2 Proof of Lemma 2

The equilibrium investment levels, as also written in the main body of the paper, are:

$$\begin{aligned} m^N =& \frac{2\beta(a - c)}{9\phi - 2\beta^2} \\ m^B =& \frac{4\beta(a - c)}{9\phi - 4\beta^2} \\ m^{JV} =& \frac{\beta(a - c)}{2\phi - \beta^2} \end{aligned}$$

From these equations, the following relationship is obtained:

$$\begin{aligned} m^{JV} &> m^B \\ m^{JV} &> m^N \\ m^B &> m^N \end{aligned}$$

A.1.3 Proof of Proposition 1

Consumer surplus is defined as:

$$CS^l = \frac{(Q^{l*})^2}{2}$$

with $Q^l = q_1^l + q_2^l$.

Therefore, to know whether consumer welfare is higher or lower in a case rather than in the other, it is sufficient to compare the total industry output. The following level of equilibrium industry outputs is obtained:

$$\begin{aligned} Q^N =& \frac{6(a-c)\phi}{9\phi - 2\beta^2} \\ Q^B =& \frac{6(a-c)\phi}{9\phi - 4\beta^2} \\ Q^{JV} =& \frac{(a-c)\phi}{2\phi - \beta^2} \end{aligned}$$

By comparing these three industry output levels, the following relationship is obtained:

$$\begin{aligned} &Q^B > Q^N \\ &Q^B > Q^{JV} \\ &Q^{JV} > Q^N \text{ unambiguously if } 3\phi < 4\beta^2 \end{aligned}$$

We now turn to the part regarding total welfare. We obtain the following levels of total welfare in equilibrium:

$$\begin{aligned} W^N =& \frac{2(a-c)^2(18\phi - \beta^2)\phi}{9\phi - 2\beta^2} \\ W^B =& \frac{4(a-c)^2(9\phi - 2\beta^2)\phi}{9\phi - 4\beta^2} \\ W^{JV} =& \frac{(a-c)^2(3\phi - \beta^2)\phi}{2(2\phi - \beta^2)} \end{aligned}$$

By comparing the total welfare levels in the different cases, taking each time into considerations the assumption on the parameters and the second order conditions,

the results reported in the Proposition are obtained.

A.1.4 Basic Investment Sharing with late entrant: choice of outsider's access price

The outsider has the option to ask access to the NGN or to use the copper network and obtain access at regulated conditions (i.e. $r_c = c_c = c$). The superscript E denotes the case of exclusion of the outsider from the NGN. If the outsider decides to use the copper network, the three firms profits are the following:

$$\begin{aligned}
\pi_1^{B,E} &= (\frac{a - c + 2\beta m^B}{4})^2 - \frac{(m^B)^2\phi}{4} \\
\pi_2^{B,E} &= (\frac{a - c + 2\beta m^B}{4})^2 - \frac{(m^B)^2\phi}{4} \\
\pi_3^{B,E} &= (\frac{a - c - 2\beta m^B}{4})^2
\end{aligned}$$

where the superscript E denotes the case of exclusion of the outsider from the NGN.

The outsider will choose to use the NGN only if:

$$\begin{aligned}
&\pi_3^B \geq \pi_3^{B,E} \\
&(\frac{a + 2c + \beta m^B - 3r^{B,L}}{4})^2 \geq (\frac{a - c - 2\beta m^B}{4})^2 \\
&r^{B,L} \leq c + \beta m^B
\end{aligned}$$

Bearing this in mind, the co-investing firms choose the outsider's NGN access charge. The access charge that maximises the co-investors joint profits, obtained from the first order conditions, is equal to:

$$r^{B,L} = \frac{2(a + \beta m^B) + 3c}{5}$$

At this level of access charge, the outsider quantity is less than in the outside option, therefore there is exclusion. The co-investing firms equilibrium profits when

the late entrant is excluded from the NGN but is active on the copper network are:

$$\pi_i^{B,E} = \frac{(a-c)^2\phi}{16(\phi-\beta^2)}$$

with $i, = 1, 2$. If the entrant is also excluded from the copper network, it is possible to refer to the equations for the case with basic investment sharing with two firms.

Alternatively, the co-investing firms can charge the highest access charge that keeps the outsider in the NGN market, $r^{B,L} = c + \beta m^B$, and earn the following profits in equilibrium:

$$\pi_i^B = \frac{(a-c)^2(9\beta^2+4\phi)}{64\phi}$$

By comparing the levels of equilibrium profits of the co-investing firms, it is found that:

$$\pi_i^B \geq \pi_i^{B,E} \text{ if } \phi > 9\beta^2/5$$

Insiders can also use the investment variable m^B to exclude the outsider. Indeed, the equilibrium quantity of the outsider when using the copper network is:

$$q_3^B = \frac{(a-c)(\phi-2\beta^2)}{4(\phi-\beta^2)}$$

This implies that, for $\phi < 9\beta^2/5$, the outsider is not only excluded from the NGN, but also from the copper network, since $\phi < 2\beta^2$ from the equation above. This happens when the consumers' willingness to pay for ultra-fast broadband services, β, is relatively larger than the investment cost, ϕ. The comparison between insiders' profits when the outsider is out of the broadband market and the insiders' profits when they include the outsider in the NGN confirms that, for $\phi < 9\beta^2/5$, there is always exclusion.

Therefore, the optimal choice of access charge becomes:

$$r^{B,L} = \begin{cases} \frac{2(a+\beta m^B)+3c}{5} & \text{if } \phi < 9\beta^2/5 \\ c + \beta m^B & \text{otherwise} \end{cases}$$

A.1.5 Joint-venture Investment Sharing with late entrant: choice of outsider's access price

In the joint-venture investment sharing case, the outsider will choose the NGN only if its profit is not lower than with the copper network:

$$\pi_3^{JV} \geq \pi_3^{JV,E}$$
$$(\frac{a+c+\beta m^{JV}-3r_o^{JV,L}+r_I^{JV,L}}{4})^2 \geq (\frac{a-2c-2\beta m^{JV}+r_I^{JV,L}}{4})^2$$
$$r_o^{JV,L} \leq c+\beta m^{JV}$$

Bearing this in mind, the co-investing firms choose the outsider's NGN access charge. The access charge that maximises the co-investors joint profits, obtained from the first order conditions, is equal to:

$$r_o^{JV,L} = \frac{a+c+\beta m^{JV}}{2}$$

At this level of access charge, the outsider quantity is less than in the outside option, therefore there is exclusion of the outsider from the NGN. In this case the co-investors set their internal transfer $r_I^{JV,L} = c$. The equilibrium profit when the late entrant is excluded from the NGN but is active on the copper network and $r_I^{JV,L} = c$ is:

$$\pi_i^{JV,E} = \frac{(a-c)^2\phi}{16(\phi-\beta^2)}$$

with $i, = 1, 2$. If the entrant is also excluded from the copper network, it is possible to refer to the equations for the case with joint-venture investment sharing with two firms.

Alternatively, the co-investing firms can charge the highest access charge that keeps the outsider in the NGN market, $r_o^{JV,L} = c+\beta m^{JV}$. At this level of outsider's access charge, the insider's NGN fee is $r_I^{JV,L} = r_o^{JV,L}$ and the insiders' equilibrium profits are:

$$\pi_i^{JV} = \frac{(a-c)^2(2\beta^2+\phi)}{4(4\phi-\beta^2)}$$

By comparing the levels of equilibrium profits of the co-investing firms, it is

found that:

$$\pi_i^{JV} \geq \pi_i^{JV,E} \text{ if } \phi > 8\beta^2/5$$

As in the previous case, insiders can strategically use the investment variable m^{JV} to exclude the outsider. Given the value of the internal transfer, the equilibrium quantity for the outsider when using the copper network is:

$$q_3^{JV} = \frac{(a-c)(\phi - 2\beta^2)}{4(\phi - \beta^2)}$$

This implies that, for $\phi < 8\beta^2/5$, the outsider is not only excluded from the NGN, but also from the copper network market, since $\phi < 2\beta^2$ from the equation above. The comparison between insiders' profits when the outsider is out of the broadband market and the insiders' profits when they include the outsider in the NGN confirms that, for $\phi < 8\beta^2/5$, there is always exclusion.

Therefore, the optimal choice of outsider's access charge is:

$$r_o^{JV,L} = \begin{cases} \frac{a+c+\beta m^{JV}}{2} & \text{if } \phi < 8\beta^2/5 \\ c + \beta m^{JV} & \text{otherwise} \end{cases}$$

A.1.6 Proofs of Lemmas 3 and 4 and Propositions 2 and 3

Firstly, the results in terms of retail competition for any level of investment, investment levels, and welfare, in the case of basic investment sharing, joint-venture investment sharing and no investment sharing, with two insiders and one outsider to the agreement, respectively, are reported:

$$Q^B(m) = \frac{3a - 3c + 2\beta m}{4}$$
$$Q^{B,E}(m) = \frac{2(a - c + \beta m)}{3}$$
$$Q^{JV}(m) = \frac{3a - 3c + \beta m}{4}$$
$$Q^{JV,E}(m) = \frac{a - c + \beta m}{2}$$
$$Q^N(m) = \frac{3(a - c + \beta m)}{4}$$

From these findings, the statement in Lemma (3) is drawn.

$$m^{B*} = \begin{cases} \frac{4\beta(a-c)}{9\phi-4\beta^2} & \text{if } \phi < 9\beta^2/5 \\ \frac{3\beta(a-c)}{4\phi} & \text{otherwise} \end{cases}$$
$$m^{JV*} = \begin{cases} \frac{\beta(a-c)}{2\phi-\beta^2} & \text{if } \phi < 8\beta^2/5 \\ \frac{3\beta(a-c)}{4\phi-\beta^2} & \text{otherwise} \end{cases}$$
$$m^{N*} = \frac{\beta(a-c)}{8\phi-\beta^2}$$

From these findings, the statement in Lemma (4) is drawn.

$$Q^{B} = \begin{cases} \frac{6(a-c)\phi}{9\phi-4\beta^2} & \text{if } \phi < 9\beta^2/5 \\ \frac{3(a-c)(2\phi+\beta^2)}{8\phi} & \text{otherwise} \end{cases}$$
$$Q^{JV} = \begin{cases} \frac{(a-c)\phi}{2\phi-\beta^2} & \text{if } \phi < 8\beta^2/5 \\ \frac{3(a-c)\phi}{4\phi-\beta^2} & \text{otherwise} \end{cases}$$
$$Q^{N} = \frac{6(a-c)\phi}{8\phi-\beta^2}$$

$$W^{B} = \begin{cases} \frac{4(a-c)^2(9\phi-2\beta^2)\phi}{9\phi-4\beta^2} & \text{if } \phi < 9\beta^2/5 \\ \frac{3(a-c)^2(9\beta^4+16\beta^2\phi+20\phi^2)}{128\phi^2} & \text{otherwise} \end{cases}$$
$$W^{JV} = \begin{cases} \frac{(a-c)^2(3\phi-\beta^2)\phi}{2(2\phi-\beta^2)} & \text{if } \phi < 8\beta^2/5 \\ \frac{3(a-c)^2\phi(\beta^2+5\phi^2)}{2(4\phi-\beta^2)^2} & \text{otherwise} \end{cases}$$

From these results, the statement in Proposition (3) is drawn, bearing in mind that exclusion of the outsider might emerge depending on the parameters.

Finally, in the regulated case, which is denoted with superscript r, it is assumed that the regulator chooses a uniform NGN access charge, disregarding the belonging to the co-investment consortium. The regulated access charge, given assumption

(2.2), is $r_r = c$. The following results are obtained:

$$Q^r(m) = \frac{3(a - c + \beta m)}{4}$$
$$m^r = \frac{\beta(a - c)}{4\phi - \beta^2}$$
$$Q^r = \frac{3(a - c)\phi}{4\phi - \beta^2}$$

In Proposition (2), the following result is stated:

$$Q^B(m) < Q^r(m)$$
$$Q^{JV}(m) < Q^r(m)$$
$$m^{B*} > m^r$$
$$m^{JV*} > m^r$$
$$CS^B > CS^r$$
$$CS^{JV} \geq CS^r$$

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