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For further information
Florence School of Regulation
Robert Schuman Centre for Advanced Studies
European University Institute
Via Boccaccio, 151
I-50133 Firenze
Tel.: +39 055 4685 751
Fax: +39 055 4685 755
E-mail: fsr@eui.eu
http://www.eui.eu/RSCAS/ProfessionalDevelopment/FSR/

Geographic Access Rules and Investments*

Marc Bourreau†, Carlo Cambini‡, Steffen Hoernig§

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Abstract

We analyze competition between vertically-integrated operators who build infrastructure and provide access in different geographical areas. Under full commitment, the regulator sets socially-optimal access rates that depend on the local degree of infrastructure competition. If he can only commit to implementing a single access price, the regulator can impose a uniform access price or deregulate access in competitive areas. While uniform access pricing leads to suboptimal investment, deregulation can spur investment. Still, deregulation is not an ideal solution to the commitment problem, as it tends to involve multiple and inefficient equilibria at the wholesale level, with either too little or too much investment.

Keywords: Next generation networks; Infrastructure investment; Geographical access regulation; Deregulation.

JEL codes: L51; L96.

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†Telecom ParisTech, Department of Economics and Social Sciences, and CREST-LEI, Paris. Email: marc.bourreau@telecom-paristech.fr.

‡Corresponding author. Politecnico di Torino; EUI - Florence School of Regulation. Email: carlo.cambini@polito.it

§Nova School of Business and Economics, INOVA, Universidade Nova de Lisboa, Lisbon, Portugal; CEPR, London, UK. Email: shoernig@novasbe.pt.

1 Introduction

Investment in broadband infrastructure is drawing extraordinary attention from governments and regulators all over the world, due to the significant impact of high-speed access networks on economic growth (Czernich et al., 2011). While regulatory intervention must create conditions that encourage (or rather, do not discourage) infrastructure investment, it should at the same time prevent the monopolization of the retail market for high-speed broadband services. The latter calls for some form of regulated access to infrastructures, while the former implies that this should be done with care.

An added complication is that competition among high-speed broadband networks is likely to emerge only in specific regions of a country, mostly in very dense metropolitan areas, while in the rest of the country infrastructure competition will probably not materialize. For the least densely populated areas, only government subsidies will make private investment viable. But even in areas covered without the need for public subsidies, the number of operators rolling out their network will differ. Large swathes of the country will most likely be left with only one high-speed network, while urban areas might be covered by two or more. From a regulatory point of view, this calls for *ex-ante* access rules to vary across areas characterized by different degrees of infrastructure competition. While this is plausible from the point of view of competition law now popular in telecommunications regulation, there is a lack of theoretical research on this type of access regime and its impact on firms' investment decisions. The aim of this paper is to fill this gap.

Our paper is motivated by recent decisions by the European Commission that forcefully push for the adoption of geographically differentiated remedies, or "geographical access rules" as they are referred to by policy makers (see e.g. ERG, 2008).[1] The 2009/140/EC Directive ("Better Regu-

[1] The association of European Telecom Regulators (ERG, 2008) provides a list of criteria to assess the homogeneity of competitive conditions in different geographical markets and to define geographical access remedies. Xavier and Ypsilanti (2011) analyze the practical complexity of geographically segmented regulation.

lation Directive") explicitly considers the possibility of defining different geographical markets and remedies according to prevailing competitive conditions.[2] This approach was recently confirmed in the EU Recommendation C(2010) 6223 on "Regulated Access to Next Generation Access Networks (NGANs)" (September 2010), with Recital 10 stating that "the transition from copper-based to fibre-based networks may change the conditions of competition in different geographic areas and may necessitate a review of the *geographical scope of markets and remedies* [...]" (emphasis added). The European legislator thus invites national regulatory authorities (NRAs) to examine differences in the degree of infrastructure competition across geographical areas, in order to determine whether the definition of subnational geographical markets or the imposition of differentiated remedies are warranted.[3]

This paper's main focus is on how regulators should account for geographical differences in their access pricing policies. We therefore study the impact of the geographical structure of regulation on firms' investment incentives and static welfare.

Our model is structured as follows. In a country composed of a continuum of areas with an increasing cost of coverage, two incumbent operators decide to deploy their own networks where investment can be recouped by retail profits. Two types of areas can emerge: Single infrastructure areas where only one incumbent has invested, and duplicate infrastructure areas where both incumbents have rolled out a network. We assume that the incumbent operators must provide access to a third operator and to each other. However, access regimes can differ between areas depending on the differing degrees of infrastructure competition.

[2] Recital 7 of the Directive states: "In order to ensure a proportionate and adaptable approach to varying competitive conditions, national regulatory authorities should be able to define markets on a subnational basis and to lift regulatory obligations in markets and/or geographic areas where there is effective infrastructure competition."

[3] For current broadband services, national regulators in the UK (Ofcom, 2007) and Portugal (Anacom, 2009) have already made the decision to divide the wholesale broadband market into different sub-markets according to differences in competitive conditions, and have proposed the adoption of differentiated wholesale remedies in different (competitive and non-competitive) areas. Similar decisions were recently taken by the Finnish and Hungarian NRAs (see the EC decision FI/2009/900 for Finland and HU/2007/0662-663 for Hungary).

Regulatory commitment has a strong impact on investment incentives. If the regulator faces no commitment or information problem, he can implement duplication-based remedies, that is, set differentiated access prices in both the single and the duplicate infrastructure areas. However, the regulator may face an informational problem (for example, he may be unable to collect enough information to compute differentiated access charges) and/or a commitment problem. If unable to commit at all, the regulator will set access charges in both areas at marginal cost, which is a standard finding in the literature.[4] In this case, we show that as a result only one infrastructure will be deployed in equilibrium and no duplication will occur. However, this outcome is socially undesirable if duplication entails benefits in terms of higher variety or quality.

We then consider the more realistic possibility that the regulator can at least "partially" commit, in that he can commit to a single access price. Under this constraint, a standard solution that regulators have adopted is to implement a uniform access price, which naturally tends to produce a suboptimal outcome. Alternatively, regulators can differentiate regulation according to the availability of multiple facilities by setting the access price in single infrastructure areas, and leaving it "to the market" in duplicate infrastructure areas. We show that in this regulatory framework, contrary to what one might hope, market outcomes may be neither easily predictable nor efficient. First, the wholesale game between access providers has a natural tendency towards multiple equilibria. Second, none of the resulting equilibria are efficient when investment incentives are factored in: Either competition results in very low access prices which destroy investment incentives, or competition does not take off and access and retail prices remain high. In sum, we show that partial deregulation of access conditions does not solve the commitment problem, since it may create problems of its own and investment remains suboptimal even in the presence of wholesale competition.

[4] See, for example, Besanko and Spulber (1992).

Literature Review. Our paper merges two different strands of the literature. The first deals with universal service obligations (USOs), uniform pricing constraints and coverage, while the second deals with the interaction between access regulation and investment.

In the USO literature, most papers focus on the role of uniform pricing constraints and their impact on network coverage and market competition. Valletti, Hoernig, and Barros (2002) show that the introduction of uniform pricing and coverage constraints is not competitively neutral: Under uniform pricing, the equilibrium coverage may be lower than without any regulatory intervention. Similar results for the strategic links created through pricing restrictions have been found by Anton et al. (2002), Choné et al. (2000, 2002) and Foros and Kind (2003). Hoernig (2006) concentrates his analysis on the imposition of uniform pricing constraints and shows that the opening of the market to competition in the presence of uniform pricing constraints on all operators gives rise to a series of neighboring monopolies rather than competition for customers. All these papers focus on the impact of uniform pricing constraints at *retail* level on market coverage and competition. However, they do not address the possibility of geographical differentiation in broadband coverage, and they completely neglect the problem of uniform and non-uniform (i.e., geographically differentiated) *wholesale* rules on investment incentives and their impact on market competition and firms' investment, which is the focus of our paper.

The second strand of literature analyzes the impact of access regulation on firms' investment. Cambini and Jiang (2009) provide a recent and comprehensive review of both theoretical and empirical papers on broadband investment and regulation. Some studies analyze the incumbent's investment incentives (Foros, 2004; Katakorpi, 2006; Brito et al., 2010; Nitsche and Wiethaus, 2011; Mizuno and Yoshino, 2012) or the alternative operators' (Bourreau and Doğan, 2006) as a function of the access regime. Several other papers (Gans, 2001 and 2007; Hori and Mizuno, 2006; Vareda and Hoernig, 2010) study the impact of access charges in a dynamic investment race between the incumbent and the entrants. Finally, additional papers have recently focused on the interplay between access regulation and the migration from the old legacy network to an NGAN infrastructure (Bourreau, Cambini and Doğan, 2012; Brito, Pereira and Vareda, 2012; Inderst and Peitz, 2012). All the above papers address the problem of investment in broadband infrastructures and access regulation in different ways. However, none of them specifically look at the introduction of geographically differentiated access rules and the impact of geographical access remedies on market competition and firms' investment, which is the topic of this paper.

Finally, our paper analyzes the impact of the regulator's commitment power on investment. Most papers assume either full commitment from the regulator (e.g., Vareda and Hoernig, 2010; Nitsche and Wiethaus, 2011) or no commitment (e.g., Foros, 2004; Katakorpi, 2006). One exception is Brito, Pereira and Vareda (2010), who analyze the two polar cases of no commitment and full commitment. We extend their analysis by considering also the intermediate case of partial commitment.

The paper is organized as follows. In Section 2 we present the model setup. In Section 3 we analyze the regulator's choice of geographically differentiated access prices under full commitment. We also discuss the commitment issue and consider the alternative of uniform access charges when the regulator can only partially commit. In Section 4 we analyze the impact of competition-based access charges on investment incentives under partial commitment. Section 5 concludes the paper. All longer proofs can be found in the Appendix.

2 Model Setup

Two incumbent network operators (firms 1 and 2) invest in coverage of next generation access infrastructures, and an entrant (firm e) can ask for access but does not invest. The incumbent operators build infrastructures in different areas $[0, \overline{z}]$ of a country, where $\overline{z}$ is large enough so that some areas remain uncovered in equilibrium.

Cost structure. In our model we want to capture the typical cost structure of next-generation access networks. Whereas the marginal cost of running the network is independent of a customer's location, the fixed cost of linking up each customer does depend on their location. To be more precise, it is cheapest to connect a customer in densely populated areas such as urban centres, and most costly in outlying rural areas. We therefore assume that the fixed cost of coverage $c(z)$ is strictly increasing with the area z, from $c(0) = 0$. We assume that firms $i = 1, 2$ build networks that cover the contiguous areas $[0, z_i]$, with $z_i \leq \overline{z}$, with total investment cost

$$C(z_i) = \int_0^{z_i} c(x)dx.$$

We have $C'(z_i) = c(z_i)$ and $C''(z_i) = c'(z_i) > 0$, and we assume that incumbent firms face the same investment cost function. Finally, we assume that all firms have the same marginal (wholesale and retail) costs in all areas, which we normalize to zero.[5]

Access and retail competition. According to the incumbents' investment decisions, two types of areas can emerge: single infrastructure areas (SIAs), where only one incumbent has invested, and duplicate infrastructure areas (DIAs), where both incumbents have rolled out a network.[6] Contrary to papers like Valletti et al. (2002) and Hoernig (2006), we assume that firms can set a different retail price in each area, depending on competitive conditions. Hence, they obtain different profits

[5] Our modeling assumptions for the cost structure are in line with Valletti et al. (2002), for example, who assume zero marginal production costs, and that the fixed investment cost increases over areas. By contrast, Hoernig (2006) assumes an increasing marginal cost and a constant fixed investment cost. Assuming increasing marginal costs in our setting would complexify the analysis. However, since the profitability of investing in a given area would decrease over areas, we would still obtain duplicate and single infrastructure areas, and the rest of our analysis would be qualitatively similar.

[6] There are also, of course, areas with no infrastructure.

in DIAs and SIAs.[7]

We also assume that the regulator imposes an access obligation on incumbent firms' infrastructures, which allows firm e to enter the market and network owners to use each others' networks. We denote by a and $\widetilde{a}$ the access charges in DIAs and SIAs, respectively.[8,9] The possibility of access affects the outcome as follows. First, in duplicate infrastructure areas (DIAs) only one network provides access, introducing an additional source of asymmetry between incumbents. Second, in single infrastructure areas (SIAs), the incumbent provides access to both the entrant and the rival incumbent. Note that there may be a different wholesale provider in DIAs and SIAs.

We denote by $\pi_i^{(j)}(a)$ and $\widetilde{\pi}_i^{(j)}(\widetilde{a})$ the per-DIA and per-SIA profit of firm $i = 1, 2, e$ when firm $j = 1, 2$ is the wholesale provider (including all retail and wholesale revenues, but gross of investment cost). In SIAs, the access provider makes more profit than access seekers if $\widetilde{a} > 0$, due to the higher perceived marginal cost of its competitors. In DIAs, if both incumbents offer the same access price a, the entrant randomly chooses an access provider,[10] hence the (*ex ante*) expected per-DIA profit of infrastructure owner $i = 1, 2$ is $\pi^d(a) = (\pi_i^{(i)}(a) + \pi_i^{(j)}(a))/2$, where $j = 1, 2$ and $j \neq i$. All profits are continuous functions of access charges, and in the following we drop the arguments for clarity whenever possible.

We make the following assumptions on the relation between profits and access charges.[11] First, we assume that access seekers' profits are strictly decreasing in the access charges, and that there are unique access charge levels a^e, $\widetilde{a}^e > 0$ such that $\pi_e^{(j)}(a^e) = \widetilde{\pi}_e^{(j)}(\widetilde{a}^e) = 0$, that is, the entrant

[7] In some countries (e.g., Portugal), broadband operators offer discounts on the catalogue price which vary according to geographical areas. In many countries, operators also offer different qualities of service (e.g., bandwidth) according to geography, corresponding to different quality-adjusted prices.

[8] Throughout the paper, we use a tilde ($\widetilde{\ }$) on a variable to indicate that it relates to SIAs.

[9] Access charges can differ between DIAs and SIAs, but not between infrastructure operators within the same type of area. In other words, we do not discuss here the adoption of asymmetric rules across infrastructure operators.

[10] If the entrant is indifferent between two access offers for a given regulated access price, we assume that it chooses only one access provider in each type of area, e.g., due to transaction costs. An alternative assumption would be that the access seeker commits *ex ante* to using a specific network when two are present. This will not change total coverage if duplication is partial.

[11] In the working paper version (Bourreau, Cambini and Hoernig, 2012), we provide an illustrative model which satisfies these (standard) assumptions.

just breaks even.

Second, the access provider's (*ex post*) profits in DIAs and SIAs are maximized, subject to the constraint that the entrant is viable, at $a^m = \arg\max_{a \le a^e} \pi_i^{(i)}(a)$ and $\widetilde{a}^m = \arg\max_{\widetilde{a} \le \widetilde{a}^e} \widetilde{\pi}_i^{(i)}(\widetilde{a})$, respectively. No individual access provider would voluntarily set a higher access charge. On the other hand, we assume that in DIAs the rival infrastructure firm's profits $\pi_i^{(j)}(a)$ are increasing in a, e.g., because retail prices are strategic complements. As a result, $a^d = \arg\max_{a \le a^e} \pi^d(a)$ is at least as high as a^m, and $\pi^d(a)$ strictly increases in a for $a \in \left[0, a^d\right]$.

Access charges higher than a^d and $\widetilde{a}^m$ would simultaneously lead to lower expected profits for network owners and lower welfare. In other words, they would reduce coverage without any compensating welfare gains, as we will see later.[12] A benevolent regulator will therefore only select $a \le a^d$ and $\widetilde{a} \le \widetilde{a}^m$, which we will assume for the rest of the paper.

Welfare. Finally, we denote by $w(a)$ and $\widetilde{w}(\widetilde{a})$ the social welfare in DIAs and SIAs, respectively, gross of investment costs, where welfare is defined as the sum of consumer surplus and profits. In our setting, duplication of infrastructure entails two potential social benefits. First, it may have a direct effect on welfare, by bringing about a higher variety or quality of service. Second, duplication has a competitive (indirect) effect: Because the perceived marginal cost of an incumbent firm that duplicates infrastructure decreases,[13] competition becomes more intense, causing retail prices to decline. We therefore assume that $w(a) > \widetilde{w}(a)$ for all $a \ge 0$.

[12] While entry is unprofitable if $a > a^e$ and $\widetilde{a} > \widetilde{a}^e$, unregulated networks would foreclose entry if and only if the maximal profit they can make under access is less than the profit they obtain without providing access. Depending on the demand-expanding effect of entry, this may or may not be the case.

[13] Its marginal cost goes down from $\widetilde{a}$—since it was leasing access to its rival in SIAs—to 0, since it now uses its own infrastructure at marginal cost (i.e. 0, due to our normalization).

3 Duplication-Based Remedies under Full Commitment

In this section we assume that the regulator does not face any informational or commitment problem. In this case, given the presence of areas with different degrees of infrastructure competition, it is possible to set different access prices in single and duplicate infrastructure areas. In other words, the regulator can implement what we call *duplication-based remedies*.[14]

Thus, under full commitment the timing of the game is as follows. First, the regulator sets the access charges a and $\widetilde{a}$ for DIAs and SIAs, respectively. Second, firms 1 and 2 non-cooperatively decide on coverage. Third, all firms decide whether to ask for access in DIAs and SIAs. Fourth, firms compete for consumers and profits are realized. We consider subgame-perfect Nash equilibria in pure strategies. We will discuss and relax the hypothesis of full commitment at the end of the section.

Access and investment. At Stage 3, firms can ask for access in areas where an infrastructure has been rolled out. In DIAs, firm e randomly chooses an access provider, while firms $i = 1, 2$ are (at least weakly) better off using their own infrastructure than asking for access. In SIAs, where firm $i = 1$ or $i = 2$ has invested, firms $j \neq i$ ask for access; this is always optimal for them, since the assumption is that each access seeker obtains positive profits.

At Stage 2, each incumbent firm $i = 1, 2$ chooses a coverage $[0, z_i]$ so as to maximize its profit, given its rival's coverage $[0, z_j]$, with $j = 1, 2$, $j \neq i$. If firm i chooses $z_i > z_j$, it will be the access provider in the SIAs $(z_j, z_i]$. However, in the DIAs $[0, z_j]$ either firm i or firm j can be the access

[14] In the (unrealistic) case where the social planner would be able to set a different access charge in every single area, he could achieve higher total welfare, as analyzed in our working paper (Bourreau, Cambini and Hoernig, 2012).

provider, with expected per-area profits $\pi^d(a)$. Firm i's expected total profit is then

$$\Pi_i(z_i, z_j) = \begin{cases} z_i\pi^d(a) + (z_j - z_i)\,\widetilde{\pi}_i^{(j)}(\widetilde{a}) - C(z_i) & \text{if} \quad z_i \leq z_j, \\ z_j\pi^d(a) + (z_i - z_j)\,\widetilde{\pi}_i^{(i)}(\widetilde{a}) - C(z_i) & \text{if} \quad z_i > z_j. \end{cases}$$

This profit function highlights the incumbent's trade-offs with regard to the coverage decision. For small z_j, firm i chooses its coverage trading off the marginal profits derived from being an access provider in SIAs, $\widetilde{\pi}_i^{(i)}(\widetilde{a})$, and the cost of covering an additional marginal area alone. If z_j is large, on the other hand, firm i trades off the profit it obtains from remaining an access seeker in its marginal area, $\widetilde{\pi}_i^{(j)}(\widetilde{a})$, with the gains derived from becoming an infrastructure owner, i.e. $\pi^d(a)$ less the investment cost. Thus, access creates an additional opportunity cost for investment, consisting of the profits obtained after asking for access.

The following result characterizes the coverage equilibrium at Stage 2 and shows how the DIA and SIA coverage limits, z^d and $\tilde{z}^s$, respectively, vary with the access charges.[15]

Lemma 1 *Define the coverage limits z^d and $\widetilde{z}^s$ by $c(z^d) \equiv \pi^d(a) - \widetilde{\pi}_i^{(j)}(\widetilde{a})$ and $c(\widetilde{z}^s) \equiv \widetilde{\pi}_i^{(i)}(\widetilde{a})$. The equilibria of the coverage subgame are as follows:*

- *If a is small, then $z^d < \widetilde{z}^s$ and there is **Partial Duplication**: one incumbent firm covers the areas $[0, \widetilde{z}^s]$, while the other firm duplicates in the areas $\left[0, z^d\right]$. There is **No Duplication**, i.e. $z^d = 0$, if and only if $a = \widetilde{a} = 0$.*
- *Otherwise, if a is larger, there is **Full Duplication**: both incumbent firms cover the areas $\left[0, z^{fd}\right]$, where $z^{fd} \in \left[\widetilde{z}^s, z^d\right]$.*

[15] Since we model coverage strategies as intervals of areas starting from zero, equilibria where both infrastructure firms act as monopoly providers in different areas cannot emerge. This type of equilibria would arise if firms could decide whether or not to deploy a network separately in each (infinitesimal) area. Since this leads to a multiplicity of equilibria and complexifies the analysis, without necessarily being more realistic (since in practice firms tend to cover contiguous areas), we restrict the game to simpler coverage strategies.

The coverage limits z^d and $\widetilde{z}^s$ increase strictly in $a \in \left[0, a^d\right]$ and $\widetilde{a} \in [0, \widetilde{a}^m]$.

Proof. See Appendix A, where we also state the exact limits on a. ■

While the coverage limits in DIAs and SIAs, z^d and $\widetilde{z}^s$, are functions of the access charges, in the rest of the paper we mostly drop these arguments for the sake of clarity.

We now provide intuitions regarding the different outcomes. No duplication occurs when becoming a potential access provider is highly unattractive, which happens precisely when both access charges are very low. A DIA or SIA access charge at cost reduces returns on investment, while a SIA access charge at cost also increases the opportunity cost of duplicating rather than being an access seeker. With regard to social welfare, while with cost-based access the competition-enhancing effect of network duplication disappears, there is still a welfare loss from the absence of duplication, in terms of lower variety and/or quality of service.

For small though positive values of the DIA access charge a, duplication occurs in the cheapest areas, while only one infrastructure is rolled out in the more costly areas. In this case, the SIA and DIA access charges are high enough so that being an access provider is attractive, while at the same time the DIA access charge is too low to be an incentive for full duplication.

At the other extreme, with a very high DIA access charge, we obtain multiple equilibria which all involve full duplication, but with different coverage levels. The existence of multiple equilibria is due to a coordination failure between investors. Both firms would actually prefer full duplication up to z^d, but if one firm covers less, the other investor will not find it profitable to extend coverage any further on its own.

The case of full duplication involves an interesting additional issue. While the boundaries of the equilibrium region change with access charges, any interior equilibrium point remains unaffected by small changes in the access charges. Together with the fact that these equilibria are Pareto-ranked in the sense that among them a joint coverage of all areas up to z^d leads to the highest welfare and profits, this suggests an additional potential role for the regulator. This role would consist in helping firms to coordinate on the "right" equilibrium, while ensuring that coverage responds to the announced access charges.

The above Lemma also implies that SIA and DIA coverage increase in both access charges. This implies that the regulator faces the usual dilemma between setting lower access charges to maximize per-area welfare and setting higher access charges to maximize (or duplicate) coverage.[16] There is another subtler issue, however, which is that in DIAs it is necessary to distinguish between the imposition of a specific value for the access charge (as we have assumed so far) and the imposition of a cap. This distinction matters whenever the regulator wants to increase coverage through an access price above a^m, which is the maximum price that the access provider would like to charge. If the regulator sets a cap a above a^m, rather than setting the access price a, the access provider will choose *ex post* the access price $a^m < a$, which satisfies the cap, and duopoly coverage will not increase beyond $z^d(a^m, \widetilde{a})$. On the other hand, if an access price $a > a^m$ is fixed before investments are made, then the possibility of *not* being the access provider while benefiting from a high retail price level raises expected profits and increases coverage.

The regulator's trade-off. Higher access charges inflate retail prices and reduce consumption, hence decreasing per-area welfare. Social benefits from higher coverage therefore need to be traded off against social costs in terms of lower welfare per area. Infrastructure competition moreover reduces one incumbent firm's perceived marginal cost and contributes additional benefits in terms of variety or quality of service, meaning that a positive degree of duplication is optimal.

We start by discussing the trade-offs involved when there is partial duplication in the coverage

[16] Access provision can increase coverage if access charges are high enough and services are sufficiently differentiated, so that entry increases demand and joint profits.

subgame.[17] In this case, total welfare is given by

$$W = z^d w + \left(\widetilde{z}^s - z^d\right)\widetilde{w} - C(\widetilde{z}^s) - C(z^d).$$

The social benefits of covering a marginal single or duplicated area are

$$\begin{aligned}
\Delta^s &= \widetilde{w} - c(\widetilde{z}^s) = \widetilde{w} - \widetilde{\pi}_i^{(i)}, \\
\Delta^d &= w - \widetilde{w} - c(z^d) = w - \pi^d - (\widetilde{w} - \widetilde{\pi}_i^{(j)}),
\end{aligned}$$

respectively. Both expressions contain the net benefit of investment, i.e. the welfare gain less the investment cost, but Δ^d also includes the social opportunity cost of duplication, which is the social welfare forgone in a SIA, $\widetilde{w}$. While Δ^s is always positive, as it is equal to consumer surplus plus the profits of firms j and e, Δ^d may be negative for high a and low $\widetilde{a}$. On the other hand, Δ^d is positive at $a = 0$.[18]

With these definitions, the effect of the access charges on welfare is given by

$$\frac{\partial W}{\partial a} = \underbrace{z^d \frac{dw}{da}}_{\text{(-)}} + \underbrace{\Delta^d \frac{\partial z^d}{\partial a}}_{\text{(+) or (-)}}, \tag{1}$$

and

$$\frac{\partial W}{\partial \widetilde{a}} = \underbrace{\left(\widetilde{z}^s - z^d\right)\frac{d\widetilde{w}}{d\widetilde{a}}}_{\text{(-)}} + \underbrace{\Delta^s \frac{d\widetilde{z}^s}{d\widetilde{a}}}_{\text{(+)}} + \underbrace{\Delta^d \frac{\partial z^d}{\partial \widetilde{a}}}_{\text{(+) or (-)}}. \tag{2}$$

The first terms in equations (1) and (2) are negative and represent the loss in static efficiency due to higher access charges. The other terms represent the variation in welfare due the change

[17] In our working paper (Bourreau, Cambini and Hoernig, 2012), we show that both full and no duplication lead to lower social welfare.

[18] Indeed, we have $w\,(0) > \widetilde{w}(0)$ from our assumptions, and $\pi^d(0) = \widetilde{\pi}_i^{(j)}(0)$.

in coverage, keeping net per-area welfare fixed (i.e., the benefits or costs in terms of dynamic efficiency). The second term in (2) is positive, indicating that the regulator would always want to expand total coverage further by increasing $\widetilde{a}$. On the other hand, the last terms in (1) and (2) have an ambiguous sign. Since they translate the net gain from transforming a SIA into a DIA, they are positive only if the gain from increased competition and variety outweighs the investment cost and the opportunity cost of duplication. If not, then the regulator would set both lower a and $\widetilde{a}$ in order to limit duplication.

What is clear, however, is that different trade-offs underlie the optimal choice of access charges in DIAs and SIAs, respectively. Therefore, the resulting optimal access charges a^{so} and $\tilde{a}^{so}$ can only be equal by chance. The following result summarizes this analysis.

Proposition 1 *Under full commitment, the regulator optimally sets different access charges a^{so} in DIAs and $\tilde{a}^{so}$ in SIAs, taking into account the relevant trade-offs between static and dynamic efficiency.*

While the above trade-offs do not allow us to make a clear-cut statement about the relative sizes of access charges, the fact that the access provision in SIAs limits the feasibility of duplication indicates that it should be optimal to set a relatively high access charge in SIAs and a relatively lower one in DIAs.[19]

The commitment issue. So far, we have assumed that the regulator can commit to an access scheme with different access prices for DIAs and SIAs, and evaluate the resulting trade-offs. However, the regulator may be unable to implement sophisticated duplication-based remedies, for different reasons.

[19] In our working paper we present a simulation of the optimal duplication-based access charges in an example and confirm that a will be low and $\widetilde{a}$ will be high(er).

First, the regulator might face informational constraints and be unable to gather enough information to differentiate the access charges according to geography and market structure. Second, he may be unable to commit to the access regime *ex ante*. The literature on access and investment acknowledges the problem of the regulator's commitment. For example, Foros (2004) assumes that regulatory commitment is not possible, similarly to Brito et al. (2010), who show that the adoption of a two-part access tariff partially mitigates this problem. The same assumption is made by Mizuno and Yoshino (2012).

If the regulator is unable to commit at all, then once investments have been made, he sets the access charge to marginal cost in all areas (i.e., to zero in our setting, in line with the normalization that we defined). Based on Lemma 1, cost-based access pricing implies that no duplication takes place. As we explained above, there is no duplication because an infrastructure firm can obtain the same retail revenues with or without investing into a network. However, an absence of duplication is not socially optimal because of the lost benefits in terms of variety and/or quality of service.

Even though the regulator may be unable to commit to a sophisticated access rule, he may be able to commit to a simpler rule, with a single (linear) access price, as this is standard in regulatory practice. However, we make the assumption that this access price may apply to all or only some areas. We refer to this limited commitment as a "partial commitment". Lack of information can moreover force the regulator to set a single access price. For example, ERG (2008) argues that defining different geographical markets does not imply the need to adopt differentiated remedies if this might generate excessively complex regulatory intervention.

One standard solution adopted by many regulators is to set a uniform access price for all geographical areas. However, the above discussion clearly shows that uniform access pricing is not likely to be socially optimal, and we can therefore state the following result:

Corollary 1 *Uniform access pricing leads to lower welfare than duplication-based access pricing.*

Note that the point of this corollary is not that having two instruments—in this case two access prices—is necessarily better than having just one (though it most likely is). The important issue here is that the trade-offs involved in setting the two access prices are different, and that their optimal values will therefore differ.

4 Competition-Based Remedies and Partial Commitment

We now consider an alternative regulatory regime which has been proposed by regulators (see for instance Ofcom, 2007), and which we call *competition-based remedies*. More precisely, we assume that the regulator can only partially commit. As a result, he sets the access charge in the SIAs, but does not regulate the wholesale market in the "competitive" areas (i.e., the DIAs). In DIAs incumbents can therefore set the access charge to their networks on a commercial basis. However, without any regulatory intervention the presence of wholesale competition might lead to market foreclosure (Ordover and Shaffer, 2007; Bourreau et al., 2011). Consequently, the only assumption that we make—in line with the existing regulatory framework (Directive 2009/140/EC)—is that the entrant should not be foreclosed; if that happens, the regulator will intervene as detailed below.

Though competition-based remedies might seem to be a good alternative to uniform pricing under partial commitment, in what follows we show that the resulting outcomes are not that simple due to a potential multiplicity of equilibria in the wholesale market (already identified in the literature),[20] and to the fact that these equilibria tend to have unattractive properties: They either lead to an absence of duplication or to an excessively high access price.

More precisely, we consider differentiated remedies where the regulator implements a light

[20] See Bourreau et al. (2011). Ordover and Saloner (2007) do not obtain multiple equilibria in a model of wholesale market competition similar to Bourreau et al., because they allow for full foreclosure and, under the parameter restrictions they impose, only the perfectly competitive equilibrium exists. With two vertically-integrated firms, one of which is the exogenously given wholesale provider, Höffler and Schmidt (2008) also show that introducing service-based competition can lead to higher retail prices, due to the softening effect.

regulatory approach in DIAs. Infrastructure owners can freely make private access offers to the entrant. The regulator will take action only if there is no viable access offer, in which case he imposes access at a *dispute resolution price* $a^{dr} \leq a^e$.

Foreseeing the resulting market outcome, the regulator also sets the SIA access charge in order to maximize total welfare. Note however that given the multiplicity of equilibria that emerge in the wholesale market, the regulator can only imperfectly anticipate the equilibrium that will emerge in competitive areas. The regulator therefore cannot know *ex ante* whether the SIA access charge he sets will be optimal *ex post*. This implies that deregulating access in competitive infrastructure areas generates an additional source of inefficiency: The access charge set by the regulator in SIAs is unlikely to be socially optimal *ex post*. We will come back on this point below.

We modify the timing of the game as follows. In the first stage, the regulator sets the SIA access price and the dispute resolution price a^{dr}. In the second stage, firms 1 and 2 decide on coverage. In the third stage, firms 1 and 2 make their DIA access offers $a_1, a_2 \in [0, \infty]$,[21] and then the regulator imposes $a_i = a^{dr}$ if $\min\{a_1, a_2\} > a^e$. Firms subsequently decide whether to ask for access in any given area. Finally, in the fourth stage they compete for consumers.

Again, we proceed by backward induction. The equilibrium at the retail competition stage is the same as above, given access prices $\tilde{a}$ and a, where $a = \min\{a_1, a_2\}$. We now consider access decisions at Stage 3. In SIAs, where only firm i has invested, firm $j \neq i$ and firm e ask for access at the regulated access price $\widetilde{a}$. In DIAs, on the other hand, the entrant chooses the incumbent with lower access price a_i or selects one firm randomly if $a_1 = a_2$.

We now determine the incumbent networks' choice of the DIA access charges a_i at Stage 2. As shown by Bourreau et al. (2011), more than one equilibrium outcome may exist. As one might expect, competitive bidding for access could ensue, with a resulting equilibrium at marginal

[21] Setting the access price to infinity is tantamount to not making an access offer.

cost. On the other hand, access provision changes strategic behavior in the retail market: The access-providing incumbent becomes a less aggressive competitor, since a high access price makes it unattractive to compete for retail customers. This corresponds to the "fat-cat effect" (Fudenberg and Tirole, 1984) or "softening effect" (Bourreau et al., 2011). Thus, the access provider will set a high retail price and rely mostly on wholesale profits. As a result, the owner of the other infrastructure feels little retail pricing pressure and may obtain higher retail profits than the access provider himself.

More precisely, we assume that $\pi_j^{(i)}(0) = \pi_i^{(i)}(0)$, and that there exists an access charge $a^* > 0$ such that $\pi_j^{(i)}(a^*) = \pi_i^{(i)}(a^*)$ and $\pi_j^{(i)}(a) > \pi_i^{(i)}(a)$ if and only if $a > a^*$. For access charges above a^* each infrastructure firm prefers its rival to offer access, in which case competition for providing access may not arise. On the other hand, if access charges are below a^* then each firm prefers to be the access provider. The structure of the equilibria depends on whether a^* lies above or below the profit-maximizing access charge a^m. In an example with a linear demand system with differentiation à la Shubik and Levitan, Bourreau et al. (2011) show that a^* lies below a^m if services are sufficiently homogeneous. With more homogeneous goods, the relative gains from weaker competition due to a high access charge are greater than the losses due to fewer wholesale customers.[22]

Furthermore, the regulator's dispute resolution procedure also has surprising effects on potential equilibria. Depending on the level of the dispute resolution price additional equilibria can arise, as summed up in the following Lemma.

Lemma 2 *All wholesale pricing equilibria are given by the following:*

1. *a "competitive equilibrium", i.e. cost-based access at* $a_1 = a_2 = 0$*;*

2. *a "dispute-resolution equilibrium" without feasible access offers, if the dispute resolution price*

[22] Using the same demand model, Bourreau, Cambini and Hoernig (2012) show that a^* is always below the foreclosure access level, a^e. In what follows we assume that $a^* < a^e$.

is high, i.e. $\pi^d(a^{dr}) \geq \pi_i^{(i)}(a^m)$*;*

3. *equal and high access prices, i.e.* $a_1 = a_2 = a^*$*, if* $a^* \leq a^m$*;*

4. *only one feasible but high access offer, i.e.* $a_i = a^m$ *and* $a_j \geq a^e$*, if* $a^* \leq a^m$ *and the dispute resolution price is low (i.e.,* $\pi^d(a^{dr}) \leq \pi_i^{(i)}(a^m)$*).*

Proof. See Appendix B. ■

Before discussing the economic consequences of this bewildering set of equilibria we explain why each equilibrium arises.

The intuitive explanation for the cost-based equilibrium is the rent equalization result of Fudenberg and Tirole (1985). Any access price below a^* can be profitably underbid, and the ensuing "race to the bottom" stops only when the profits of the access provider and its rival are equal, i.e. at $a = 0$ (see Figures 1 and 2). This equilibrium is unique when $a^* > a^m$ and the dispute-resolution price is low (Figure 1). On the other hand, when $a^* < a^m$ (Figure 2), there is a second symmetric equilibrium at a^*. This equilibrium also follows from rent equalization: At this access charge, infrastructure owners are indifferent between being the access provider or not, and therefore have no reason to underbid or set a higher access price in order to avoid being chosen.

The effects of the dispute resolution access charge a^{dr} may be the least expected. If it is high, then incumbents may not find it worthwhile to make feasible access offers at all. Rather, they may wait for the regulator to impose access and hope that their rival will subsequently be chosen by the entrant. In this case, the equilibrium outcome is the same as if the DIA access price had been fixed at a^{dr}.

On the other hand, for low values of the dispute resolution price a^{dr} (i.e., for $\pi^d(a^{dr}) \leq \pi_i^{(i)}(a^m)$) and if $a^* < a^m$, an additional equilibrium arises where one firm offers the monopoly access charge and the other firm refrains from making any feasible offer. Thus, a low dispute resolution price

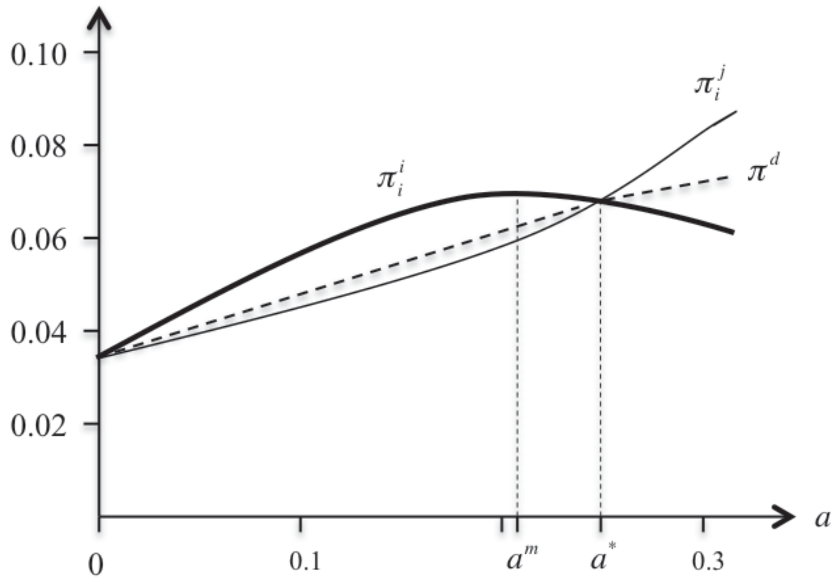

Figure 1: Profits in duplicated infrastructure areas for $a^* > a^m$.

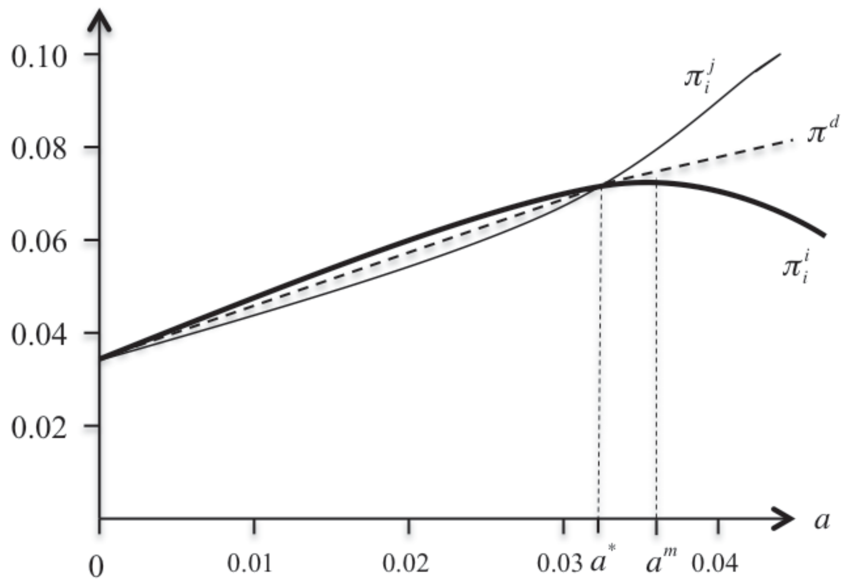

Figure 2: Profits in duplicated infrastructure areas for $a^* < a^m$.

can lead to an access market outcome at the monopoly price a^m, rather than inducing firms to necessarily settle for a low access price. This is because the firm that does not serve the wholesale market benefits from the "softening effect," and makes higher profits than if it undercuts the existing access price and becomes the access provider. Meanwhile, the access provider's profit is maximized at a^m, as not making a viable access offer is ruled out by the low dispute resolution price.

While the outcomes of the wholesale pricing game do not depend on the SIA access charge, investments at Stage 2 will depend both on the latter and on the value of the DIA access charge resulting from the wholesale market equilibrium. For each given outcome, investments will then follow from the analysis in the last section, with the additional complication that there may potentially be multiple equilibria in the wholesale market, and firms do not know which equilibrium will be played when they make their investment decisions. The latter adds an element of highly undesirable "Knightian uncertainty" to investment decisions.

Finally, we turn to the question of whether and how the regulator can achieve the optimal duplication-based outcome under wholesale competition in DIAs. In short, the answer is "yes" in some cases, but mostly "no" unless he uses further instruments. The following regulatory measures are not meant as practical proposals. Rather, our intention is to highlight the kind of (potentially difficult) intervention that would be necessary to achieve an outcome comparable to duplication-based remedies.

First, we consider the "competitive" and "dispute resolution" equilibria. These equilibria have in common that they can be achieved for a continuum of parameter combinations: the first one since it is a corner solution, and the second one because the regulator can adjust the dispute resolution price. Recall from Section 3 that a^{so} is the socially optimal DIA access charge when the regulator sets differentiated access charges.

Proposition 2 *Apart from knife-edge outcomes, the equilibrium under light regulation corresponds* *to the optimal outcome under duplication-based remedies only if either i)* $a^{so} = 0$*, or ii)* $\pi^d(a^{so}) \geq \pi_i^{(i)}(a^m)$ *and the regulator sets* $a^{dr} = a^{so}$*.*

Proof. The competitive equilibrium at $a = 0$ always exists, and $a^{so} = 0$ occurs for non-trivial set of parameters since it is a boundary solution. The dispute resolution equilibrium exists whenever $\pi^d(a^{dr}) \geq \pi_i^{(i)}(a^m)$, and the regulator can choose such a value for a^{dr} whenever $\pi^d(a^{so}) \geq \pi_i^{(i)}(a^m)$. The other equilibria, if they exist, are only efficient if, by chance, either $a^{so} = a^*$ or $a^{so} = a^m$. ■

Evidently, the dispute resolution equilibrium at $a^{dr} = a^{so}$ involves the same information and commitment issues discussed earlier, and therefore does not seem to be very feasible as a regulatory proposal. If, due to these or other issues, the regulator sets a dispute resolution price close to the upper limit a^e, then the resulting equilibrium will involve excessively high access charges.

On the other hand, if the socially optimal access charge is above a^*, then curiously the social optimum can only be achieved in this equilibrium where first the firms refuse to grant access and then the regulator imposes the socially optimal access price. It cannot be achieved with wholesale prices chosen freely by the market. Note also that the latter equilibrium will always coexist with the competitive equilibrium, and that the regulator cannot rule wholesale competition driving the access charge far below a^*.

As concerns the "competitive" equilibrium, in Bourreau, Cambini and Hoernig (2012) we show in an example that for sufficiently differentiated goods the optimal DIA access charge is indeed zero. Thus, in theory the "competitive" equilibrium can be efficient. On the other hand, with less differentiated goods we have $a^{so} > 0$, and the outcome $a = 0$ leads to inefficiently low duplication incentives. In this case, the optimal outcome can be achieved only if the regulator has some means for stopping the competitive process at a^{so}, for example if he can impose a *floor* access price at this level.

To sum up, competition-based wholesale regulation cannot generally achieve the socially optimal outcome under duplication-based remedies. Whether and how it does, though, depends on the fine details of consumer demand and on how the (de)regulation is implemented. The informational requirements and commitment powers for such instruments are essentially the same as those for duplication-based remedies. It follows that under partial commitment the regulator cannot secure the necessary incentives for network duplication. Thus, allowing for wholesale competition does not automatically solve the regulator's commitment problem nor lead to better market outcomes.

5 Conclusions

One of the recent and hotly debated issues under the new EU regulatory framework—which aims at fostering investment in new high-speed broadband networks—is the introduction of geographically differentiated remedies, that is, differentiated wholesale access schemes that vary according to the degree of infrastructure competition in local markets. In this paper we focused on this policy issue and explicitly considered the possibility for a regulator to impose geographically differentiated access remedies, and assessed the impact of alternative regulatory access regimes on investment incentives.

If the regulator has enough information and faces no commitment problem, he can implement duplication-based remedies, that is, differentiated (and socially optimal) access charges in single and duplicated infrastructure areas. However, he may face informational and/or commitment problems and not be able to set two different access prices. We therefore analyze the market outcomes if the regulator can commit only partially, by setting a single access price. The standard response to this constraint, until now adopted by most regulators, is to set a uniform access price. However, we show that uniform access pricing never achieves the social optimum because it cannot solve the different trade-offs that arise, with respect to coverage vs. static welfare, and duplication vs.

coverage by a single infrastructure.

An alternative proposal is to set the access price in single infrastructure areas only, while leaving the access price in duplicate infrastructure areas "to the market". We analyze the resulting equilibria and show that multiple market outcomes are possible. Furthermore, the intricacies of wholesale competition imply that equilibrium wholesale prices can be either too high or too low from a social point of view. Thus, the main finding of our paper is that partial deregulation is not a miracle solution to the commitment problem and that these more "market-oriented" outcomes tend not to be socially optimal without further regulatory intervention.

Our framework may be fruitfully extended into different directions. Obviously, our setting is static, hence each operator plays only once and investments are one-shot. A natural extension might be to introduce some dynamics in investment decisions. This would imply that the size of competitive and non-competitive areas change over time, calling for a dynamic adjustment of access remedies. A second, more practical, issue is the implementation of geographical remedies that might involve additional administrative costs for the regulator due to the continuous adaptation of wholesale regimes as competitive conditions change over time. We leave these interesting potential extensions for future research.

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Appendix

Appendix A: Proof of Lemma 1

Proof. Assume that firm j has covered the areas $[0, z_j]$. Firm i's profit is then

$$\Pi_i(z_i, z_j) = \begin{cases} z_i \pi^d(a) + (z_j - z_i)\,\widetilde{\pi}_i^{(j)}(\widetilde{a}) - C(z_i) & \text{if} \quad z_i \leq z_j, \\ z_j \pi^d(a) + (z_i - z_j)\,\widetilde{\pi}_i^{(i)}(\widetilde{a}) - C(z_i) & \text{if} \quad z_i > z_j. \end{cases}$$

The interior maximum on the first branch is obtained when the first-order condition holds, that is, when $\pi^d(a) - \widetilde{\pi}_i^{(j)}(\widetilde{a}) = c(z_i)$. Since $\pi^d(0) = \widetilde{\pi}_i^{(j)}(0)$ and $\pi^d(a)$ increases with a, while $\widetilde{\pi}_i^{(j)}(\widetilde{a})$ decreases with $\widetilde{a}$, we have $\pi^d(a) \geq \widetilde{\pi}_i^{(j)}(\widetilde{a})$ for all $a \in [0, a^m]$ and $\widetilde{a} \in [0, \widetilde{a}^m]$. We therefore obtain that $z_i = z^d \equiv c^{-1}(\pi^d(a) - \widetilde{\pi}_i^{(j)}(\widetilde{a}))$. Similarly, the interior maximum on the second branch is obtained at $\widetilde{\pi}_i^{(i)}(\widetilde{a}) = c(z_i)$, or $z_i = \widetilde{z}^s \equiv c^{-1}(\widetilde{\pi}_i^{(i)}(\widetilde{a}))$. In both cases the necessary second-order conditions hold, since $-c(z_i) \leq 0$. Thus, firm i's local best responses are $\min\left\{z_j, z^d\right\}$ on the first branch, and $\widetilde{z}^s$ on the second branch.

For $\pi^d(a) < \widetilde{\pi}_i^{(i)}(\widetilde{a}) + \widetilde{\pi}_i^{(j)}(\widetilde{a})$, which implies $0 \leq z^d < \widetilde{z}^s$, the global best response to $z_j \leq z^d$ is $z_i = \widetilde{z}^s$, while the best response to $z_j \geq \widetilde{z}^s$ is $z_i = z^d$. Symmetry then implies that the only equilibria are $\left(z^d, \widetilde{z}^s\right)$ and $\left(\widetilde{z}^s, z^d\right)$. For $a = \widetilde{a} = 0$, we obtain $z^d = 0$ (as $\pi^d(0) = \widetilde{\pi}_i^{(j)}(0)$) and thus no duplication, while for $a > 0$ or $\widetilde{a} > 0$ we have $\pi^d(a) > \widetilde{\pi}_i^{(j)}(\widetilde{a})$ and thus partial duplication.

On the other hand, for $\pi^d(a) \geq \widetilde{\pi}_i^{(i)}(\widetilde{a}) + \widetilde{\pi}_i^{(j)}(\widetilde{a})$, we have $0 < \widetilde{z}^s \leq z^d$. The global best response is $\widetilde{z}^s$ for $z_j \leq \widetilde{z}^s$ and $\min\left\{z_j, z^d\right\}$ for $z_j > \widetilde{z}^s$. Thus, by symmetry, all equilibria are given by any $\left(z^{fd}, z^{fd}\right)$ with $z^{fd} \in \left[\widetilde{z}^s, z^d\right]$, in which case there is full duplication.

The ranges indicated in the Lemma now follow from the fact that π^d is strictly increasing on $[0, a^m]$ and therefore has a strictly increasing inverse function, thus $\widetilde{z}^s > z^d$ if and only if $\pi^d(a) < \widetilde{\pi}_i^{(i)}(\widetilde{a}) + \widetilde{\pi}_i^{(j)}(\widetilde{a})$, i.e. if a is small enough. The comparative statics for coverage ranges follow directly from $d\pi^d/da > 0$ for all $a \in [0, a^m)$, and $d\widetilde{\pi}_i^{(i)}/d\widetilde{a} > 0$ and $d\widetilde{\pi}_i^{(j)}/d\widetilde{a} < 0$ for all $\widetilde{a} \in [0, \widetilde{a}^m)$. ■

Appendix B: Proof of Lemma 2

Proof. Let us first consider symmetric equilibrium candidates $a \in [0, a^e)$, where both infrastructure firms earn $\pi^d(a)$. Any deviation by firm $i = 1, 2$ to $a' < a$ leads to profits $\pi_i^{(i)}(a')$, while an upwards deviation to $a'' > a$ yields $\pi_i^{(j)}(a)$, since the access price that is charged in the latter case is still a. If $\pi_i^{(i)}(a) \neq \pi_i^{(j)}(a)$, then a profitable deviation exists, since $\pi^d(a)$ is their average. On the other hand, they are equal if either $a = 0$ or $a = a^*$. At $a = 0$, there are no profitable deviations, thus $a_1 = a_2 = 0$ (i.e., cost-based access) is an equilibrium. At $a = a^*$, one firm will deviate to a^m if and only if $a^* > a^m$. Thus, $a_1 = a_2 = a^*$ is an equilibrium too if $a^* \leq a^m$.

We now consider asymmetric equilibrium candidates $0 \leq a_i < a_j < a^e$, yielding profits $\pi_i^{(i)}(a_i)$ and $\pi_j^{(i)}(a_i)$. First, for $a_i = 0$ firm i increases its profits by deviating to some $0 < a < a_j$. Second, if $0 < a_i < a^*$, firm j can increase its profits by underbidding. Third, if $a_i \geq a^*$, firm i can increase its profits to $\pi_i^{(j)}(a_j)$ by increasing its access price just beyond a_j. Thus, there is no asymmetric equilibrium with $a_j < a^e$.

Now, consider asymmetric equilibrium candidates with $a_i < a^e \leq a_j$, with profits $\pi_i^{(i)}(a_i)$ and $\pi_j^{(i)}(a_i)$. The best choice for firm i, if $a_i < a^e$, is then to set $a_i = a^m$ and earn the profits $\pi_i^{(i)}(a^m)$, while for $a_i \geq a^e$ the dispute resolution procedure is triggered which leaves firm i with profits $\pi^d(a^{dr})$. Firms will not deviate from $a_i = a^m$ and $a_j \geq a^e$ if $\pi_i^{(i)}(a^m) \geq \pi^d(a^{dr})$ and $a^* < a^m$.

Finally, firms not making feasible access offers, i.e. $\min\{a_i, a_j\} \geq a^e$, leads to profits $\pi^d(a^{dr})$, from which networks will not deviate if and only if $\pi^d(a^{dr}) \geq \pi_i^{(i)}(a^m)$. ■

Authors contacts:

Marc Bourreau

Telecom ParisTech

Department of Economics and Social Sciences

46 rue Barrault

75013 Paris

France

Email: marc.bourreau@telecom-paristech.fr

Carlo Cambini

Politecnico di Torino

Corso Duca degli Abruzzi, 24

I-10129 Torino

European University Institute

Florence School of Regulation

Via Boccaccio, 151

I-50133 Firenze

Email: carlo.cambini@polito.it

Steffen Hoernig

Faculdade de Economia

Universidade Nova de Lisboa

Campus de Campolide

1099-032 Lisboa

Centre for Economic Policy Research (CEPR)

2nd Floor, 53-56 Great Sutton Street

London EC1V 0DG

UK

Email: shoernig@novasbe.pt