Co-investment Deterrence*

Ángel L. López† Anton-Giulio Manganelli‡ María Martín-Rodríguez§

November 2021

Abstract

We examine co-investment and access in a model of new network deployment. We show that the incumbent firm may find it optimal to deter co-investment by over-investing when the cost-sharing rule is based on its verified expenditure and the information on the deployment cost is asymmetric between the operators and the regulator. When partial deterrence is optimal, it occurs in the areas of intermediate attractiveness, consistently with the evidence found in other industries. A necessary and sufficient condition for deterrence to occur is that local industry profits are lower with than without co-investment. Results are robust to demand uncertainty.

Keywords: access, co-investment, deterrence, over-investments

JEL codes: L96, L51.

1 Introduction

Network industries, like energy and telecommunications, require heavy investments to roll-out new infrastructure. Welfare depends on both the total coverage and the market structure, with monopoly normally favoring the former but harming the latter. Authorities introduced access obligations to promote competition but, since total coverage was affected, co-investment emerged as an alternative for keeping the investments in coverage by sharing the cost among competitors.

Bourreau et al. (2018), and more recently Bourreau et al. (2021), examine co-investment and access when the deployment cost is common knowledge. We consider asymmetric information between the operators and the regulator, so that the realized cost is verifiable but only the operators know the true deployment cost. The incumbent can thus over-invest to deter co-investment regardless of whether the demand is certain or uncertain (the latter is shown in the

*López acknowledges the financial support from the Spanish Ministry of Science and Competitiveness through grant RTI2018-097434-B-100, and from AGAUR under 2017SGR1301. Martín-Rodríguez acknowledges the financial support from the Japan Society for the Promotion of Science through grant KAKENHI 19K01649. We thank Makoto Hanazono, the editor Joe Harrington and two anonymous referees. The usual disclaimer applies.

†Corresponding author: Ángel L. López, Departament d'Economia Aplicada, Universitat Autònoma de Barcelona, 08193 Bellaterra (Barcelona, Spain) and Public-Private Sector Research Center, IESE Business School. Tel. +34 935 811 528. E-mail address: angelluis.lopez@uab.cat

‡Anton-Giulio Manganelli, EADA Business School, C. d'Aragó, 204, 08011 Barcelona (Spain) and CRES, Universitat Pompeu Fabra, C. Ramon Trias Fargas, 25-27, 08005 Barcelona. E-mail address: amanganelli@eada.edu

§María Martín-Rodríguez, Graduate School of Economics, Nagoya University. Furo-cho, Chikusa-ku, Nagoya 464-8601, Japan. Tel. +81 052 789 2365. E-mail address: mmartin@soec.nagoya-u.ac.jp

Appendix), since the entrant refrains from co-investing for high enough realized costs and the regulator cannot identify the over-investment.[1,2] This is in line with BEREC (2020), which advises the regulators to refer to comparable co-investment agreements and to evaluate the co-investment offers by assuming a hypothetical efficient provider.[3]

Policy documents acknowledge the possibility of deterrence in co-investment frameworks. BEREC (2016) declares that *"a distinction should be drawn between a co-investment offer, and an offer that is taken up."*[4] A recent report of the Centre on Regulation in Europe states that *"(the owners of the infrastructure) may also ask for large commitments from outsiders (e.g., in terms of number of lines to co-finance), raising barriers to entry of competitors who are unable to build their own infrastructure."*[5] Deterring practices include for example over-investments, red tape and network designs.[6,7]

Our model predicts that a necessary and sufficient condition for deterrence is that local industry profits are lower with than without co-investment. Absent access obligations, the condition reduces to local industry profits being lower under duopoly than under monopoly, which usually holds.[8] Moreover, in the partial deterrence region, over-investments are non-monotonic: deterrence happens neither in areas where deployment cost is low (since deterrence is too expensive) nor in areas where deployment cost is high (since there is no co-investment threat). The empirical literature on over-investments as deterrence tools is scarce, as it requires to estimate the ex-ante threat and the investments that would have been made lacking strategic motives. Nonetheless, qualitatively identical non-monotonic results are found in other industries.[9]

The paper proceeds as follows: Section 2 describes the model, Sections 3 and 4 analyze co-investment deterrence without and with access obligations, Section 5 presents numerical examples, and Section 6 concludes. The online appendix considers demand uncertainty.

[1] See Hart and Moore (1988) for a seminal contribution on unverifiable information and incomplete contracts, and Hermalin and Katz (1991) for an analysis of renegotiation with unverifiable actions.

[2] There is a wide literature on investments as a deterrence instrument since Spence (1977) and Salop (1979) among others. Several stylized models appear in Belleflamme and Peitz (2015), Chapter 16.

[3] BEREC (2020) states in p.17 that "national regulatory authorities (NRAs) could also use information gathered from benchmarks of comparable co-investment agreements that are already in place (. . .)", and in p.18 that "in case the NRA concludes that an efficient undertaking cannot compete effectively and sustainably when accepting the proposed terms of the co-investment offer (. . .), NRAs could potentially evaluate the terms of the co-investment offer by assuming a hypothetical efficient provider (. . .)." These recommendations are consistent with asymmetric information between the operators and the regulator.

[4] See BEREC (2016, p.7): "The mere existence of an offer, even one compliant with the conditions set out in the draft Code, should not be a sufficient basis upon which to require regulatory forbearance – if it were, then the absence of take-up could result in a de facto unregulated monopoly."

[5] See Bourreau et al. (2020, p.24).

[6] The European Commission fined Slovak Telekom for anti-competitive practices that discouraged other operators from using its network. In 2005, the Director of ST's Strategy and Regulatory Affairs Department advised in an internal email that "ST should maintain the principle of competition based on infrastructure (i.e., not allow competitors to share easily our network)." See the case AT.39523 – SLOVAK TELEKOM for details.

[7] Berkeley Research Group (2017, p.58) points out that in the French regulatory framework, where co-investment is implemented as a percentage of the total cost paid by the incumbent, "there are still advantages for the building operator because the network architecture and future investments remain under its control", so it could be in its interest to blockade co-investment.

[8] See Cabral (2000, p.325).

[9] Dafny (2005) shows that, in the inpatient procedures markets, "these (entry-deterring) incentives are strongest in markets of intermediate attractiveness". Ellison and Ellison (2011) find that "consistently with an entry-deterrence motivation, pharmaceutical incumbents in medium-sized markets advertise less prior to patent expiration."

2 Model

Following Bourreau et al. (2018), we assume a continuum of areas $z \in \mathbb{R}_+$ with identical demand. The deployment cost in a given area z is $c(z)$, which is strictly increasing and continuously differentiable with $c(0) = 0$. For exposition purposes, we make $c(z) = z$, then $C(z) = \int_0^z c(x)dx = z^2/2$.[10] Results will be qualitatively identical with any function satisfying the previous assumptions. The incumbent is denoted by 1, and the entrant by e.

Timing. The model has 3 stages. First, the incumbent decides up to which area z_1 to invest in new infrastructures, and subsequently deploys the network incurring cost $c(z) + \varepsilon_z$, with $\varepsilon_z \geq 0$, in each area z.[11] Second, the entrant decides on which covered areas to participate, through either co-investment or regulated access. Third, the incumbent obtains monopoly profits where the entrant does not participate, and both firms compete under co-investment or regulated access in the remaining areas.

Co-investment and Over-investment. Co-investment is a regulatory framework in which the entrant covers part of the cost incurred by the incumbent to get to use the network without paying any access charge.[12] Over-investments refer to unproductive investments that occur when, given deployment cost $c(z)$, the incumbent decides to incur cost $c(z) + \varepsilon_z$ with $\varepsilon_z > 0$. Since in the model the realized cost is split evenly, the entrant must pay $(c(z) + \varepsilon_z)/2$ when co-investing for any $\varepsilon_z \geq 0$. As there is no cheating or misreporting of costs, when the unproductive investment takes place, the realized cost increases. By assumption, the realized cost is verifiable but only the operators know the true roll-out cost in each area z.

We first discuss the case of pure co-investment, where there is no access option, and then consider the more general case of regulated access.

3 Pure co-investment and entry deterrence

In each area with co-investment, either firm gains duopoly profit π^d; in each of the remaining covered areas, the incumbent gains monopoly profit π^m. We first report the co-investment and coverage decisions when information is symmetric (no possibility of over-investment), as in Bourreau et al. (2018), and then examine the incumbent's incentives to deter entry and their effects on the equilibrium outcome.[13]

Co-investment. If the entrant co-invests up to covered area z, it gains $\Pi_e = z\pi^d - C(z)/2$. Therefore, the entrant co-invests in every area $z \leq \bar{z}^c \equiv 2\pi^d$.

Coverage. The incumbent chooses z_1 anticipating that the entrant will co-invest in any area with cost smaller than or equal to $\bar{z}^c$. If $z_1 \leq \bar{z}^c$, the incumbent's profits are maximized at the corner solution $z_1 = \bar{z}^c$ so there are no monopolistic areas. If $z_1 > \bar{z}^c$, there is co-investment (and thus, competition) in areas $z \leq \bar{z}^c$ and a monopoly in areas $(\bar{z}^c, z_1]$. In Bourreau et al.

[10] Bourreau et al. (2018, Appendix B) use this functional form in their numerical analysis.

[11] ε_z cannot be strictly negative even when legacy networks exist, as these are sunk costs.

[12] See Inderst and Peitz (2014) for a model with different cost-sharing rules based on the expected usage of the technology.

[13] Notice that, in the absence of access obligations, co-investment deterrence implies entry deterrence.

(2018), for $z_1 > \bar{z}^c$, the incumbent maximizes

$$\Pi_1 = (z_1 - \bar{z}^c)\pi^m + \bar{z}^c\pi^d - C(z_1) + C(\bar{z}^c)/2$$

with respect to z_1. Since the FOC yields $z_1 = \pi^m$, the incumbent chooses $z_1 = \pi^m$ when $\pi^m > 2\pi^d$, which holds when products are not too differentiated, and $z_1 = \bar{z}^c \equiv 2\pi^d$ otherwise. Consequently, there is duopolistic competition with co-investment in areas $z \in [0, \bar{z}^c]$ and a monopoly in areas $z \in (\bar{z}^c, \pi^m]$ iff $\pi^m > 2\pi^d$; otherwise, firms compete in all covered areas.

We next show when the incumbent optimally over-invests to deter entry. In any area z, the incumbent's gain from preventing entry is $\pi^m - \pi^d$. The over-investment $\varepsilon_z = 2\pi^d - c(z)$ deters entry in area z, since the entrant covers half of the realized cost: $\pi^d - (c(z) + \varepsilon_z)/2 \leq 0$. But if the incumbent deters entry, then it must also bear the cost covered by the entrant, $c(z)/2$, and thus the cost of blocking entry in area z is $\varepsilon_z + c(z)/2 = 2\pi^d - c(z)/2$. The gain from preventing entry is greater than the corresponding cost in a given area z iff $\pi^m - \pi^d \geq 2\pi^d - c(z)/2$.

Entry Deterrence with Pure Co-investment

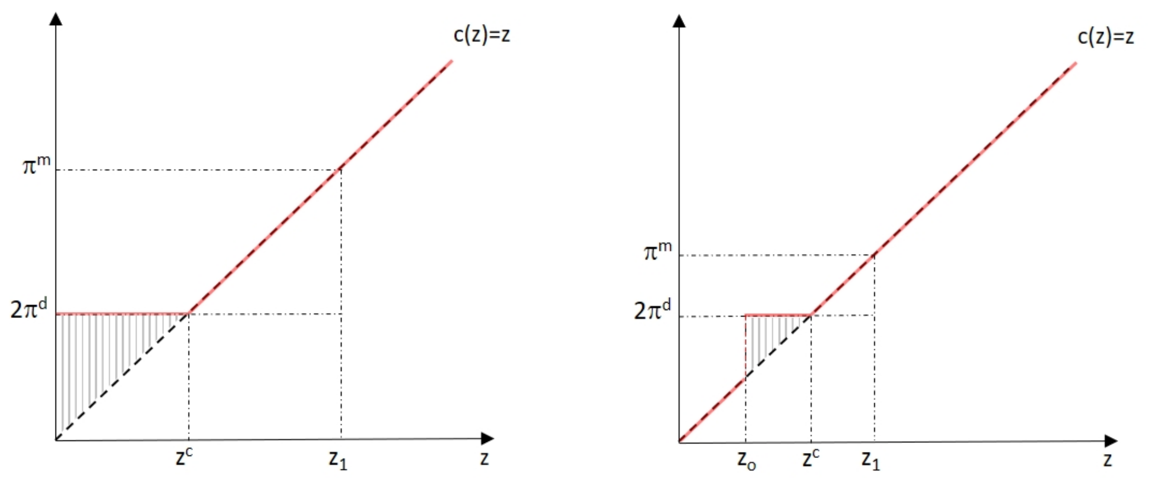

Fig. 1a. Complete entry deterrence $3\pi^d \leq \pi^m$

Fig. 1b. Partial entry deterrence $2\pi^d < \pi^m < 3\pi^d$

Complete entry deterrence ($3\pi^d \leq \pi^m$). Since the cost of blocking entry decreases with z, the incumbent finds it optimal to over-invest in areas $z \in [0, \bar{z}^c]$ iff $\pi^m - \pi^d \geq 2\pi^d$. In the remaining areas there is no entry threat, thus over-investments are not needed to monopolize areas $z \in (\bar{z}^c, z_1]$, with $z_1 = \pi^m$. Figure 1a illustrates this case, where the shaded region represents the over-investments.

Partial entry deterrence ($2\pi^d < \pi^m < 3\pi^d$). Let $z_o \in (0, \bar{z}^c)$ be the area where entry deterrence starts. The incumbent's profit is

$$\Pi_1 = z_o\pi^d + (z_1 - z_o)\pi^m - \int_0^{z_o} \frac{c(z)}{2} dz - (\bar{z}^c - z_o)2\pi^d - \int_{\bar{z}^c}^{z_1} c(z)dz,$$

with $z^1 > \bar{z}^c$. The incumbent maximizes Π_1 with respect to z_o and z_1. Note that $\partial\Pi_1/\partial z_o =$

$\pi^d - \pi^m - z_o/2 + 2\pi^d$ is strictly positive at $z_o = 0$ iff $3\pi^d > \pi^m$: it is thus optimal to allow co-investment in low cost areas. The FOCs yield $z_1 = \pi^m$ and

$$z_o = 2(3\pi^d - \pi^m).$$

Entry is not deterred in the areas $z \in [0, z_o)$, as it would be too costly, but it is in the intermediate areas $z \in [z_o, \bar{z}^c]$. As before, over-investments are not needed to monopolize areas $z \in (\bar{z}^c, z_1]$.[14] Note that $z_o < \bar{z}^c < z_1$ since $2\pi^d < \pi^m$. (See Figure 1b.)

No entry deterrence ($\pi^m \leq 2\pi^d$). Entry deterrence is not optimal when $z_o \geq \bar{z}^c$, or equivalently, when $2\pi^d \geq \pi^m$.

Summarizing:

PROPOSITION 1 *With pure co-investment:*

- *The incumbent over-invests to prevent any co-investment iff* $3\pi^d \leq \pi^m$ *(complete entry deterrence).*
- *The incumbent over-invests to prevent co-investment in the intermediate cost areas* $z \in [z_o, \bar{z}^c]$ *and allows co-investment in the low cost areas* $z < z_o$ *iff* $2\pi^d < \pi^m < 3\pi^d$ *(partial entry deterrence).*
- *There is no over-investment whatsoever iff* $\pi^m \leq 2\pi^d$ *(no entry deterrence).*

Although possible, complete deterrence is unlikely because it requires very high substitutability across products. Conversely, over-investments do not take place if and only if the products are differentiated enough: duopoly profits must not decrease much compared to monopoly profits, such that the incumbent does not over-invest and the entrant finds co-investment profitable in every region where the network has been rolled-out.

4 Access and co-investment deterrence

Now the entrant chooses between co-investing and asking for access. Access is always available, in which case the entrant must pay a regulated access charge a to the incumbent. In each area where access is requested, both firms compete and make duopoly profits $\pi_e^d(a)$ and $\pi_1^d(a)$. We follow the assumptions in Bourreau et al. (2018):

Assumption 1 *(i) There is a maximum access price,* a^{max}*, above which the entrant incurs losses; (ii)* π_1^d *(resp.* π_e^d*) is increasing (decreasing) with* a *for* $a < a^{max}$*; (iii) if* $a \geq a^{max}$*, then there is market foreclosure and the incumbent firm makes* π^m*; (iv)* $\pi_1^d(0) = \pi_e^d(0) \equiv \pi^d$ *and* $\lim_{a \to a^{max}} \pi_1^d(a) \leq \pi^m$*.*

Consider the relevant case with $0 < a < a^{max}$ and $\pi^d > \pi_e^d(a)$. Here, $\pi_e^d(a) > 0$ in each region z so, if there was no co-investment option, then the entrant would simply ask for access in every covered area; that is, in every z with $z \leq \bar{z}^a(a)$, being $\bar{z}^a(a) \equiv \arg\max_{z_1} z_1\pi_1^d(a) - C(z_1) = \pi_1^d(a)$.

[14] This result is consistent with the empirical findings by Dafny (2005) and Ellison and Ellison (2011) in other industries.

The entrant prefers co-investment over access in area z iff $\pi^d - c(z)/2 \geq \pi_e^d(a)$ or, equivalently, iff

$$z \leq \bar{z}^{ca}(a) \equiv 2\left[\pi^d - \pi_e^d(a)\right].$$

When $z_1 < \bar{z}^{ca}(a)$, the entrant always co-invests and waives the access. However, there are less incentives to co-invest when access is available ($\bar{z}^{ca} < \bar{z}^c$), so the incumbent's profits are increasing on this branch and thus $z_1 \geq \bar{z}^{ca}(a)$. If the incumbent's profits are maximized at the corner solution $z_1 = \bar{z}^{ca}(a)$, then the entrant co-invests in all covered areas. If $z_1 > \bar{z}^{ca}(a)$, the entrant co-investments in areas $z \leq \bar{z}^{ca}(a)$ and asks for access in areas $z \in (\bar{z}^{ca}(a), z_1]$ (i.e., there are covered areas expensive enough for the entrant to avoid co-investment). When over-investments are not allowed, as in Bourreau et al. (2018), for $z_1 > \bar{z}^{ca}(a)$, the incumbent maximizes

$$\Pi_1 = \left[z_1 - \bar{z}^{ca}(a)\right]\pi_1^d(a) + \bar{z}^{ca}(a)\pi^d - C(z_1) + C(\bar{z}^{ca}(a))/2$$

with respect to z_1. The solution is $z_1 = \bar{z}^a(a) = \pi_1^d(a)$: coverage is the same as when there is no co-investment option iff $\pi_1^d(a) > 2\left[\pi^d - \pi_e^d(a)\right]$, and it increases to $z_1 = 2\left[\pi^d - \pi_e^d(a)\right]$ otherwise. Then, the entrant co-invests in areas $[0, \bar{z}^{ca}(a)]$ and requests access in areas $(\bar{z}^{ca}(a), \pi_1^d(a)]$ iff $\pi_1^d(a) > 2\left[\pi^d - \pi_e^d(a)\right]$; otherwise, it co-invests in all covered areas.

We next show that, with access obligations, the incumbent also may over-invest. Contrary to the case without access, here the entrant makes positive profits when co-investment is deterred since $\pi_e^d(a) > 0$: over-investments can deter co-investment but not entry. Moreover, with access obligations, the over-investments to attain deterrence are lower.[15]

[15] The over-investments to completely deter co-investment with and without access obligations are, respectively, $2\left[\pi^d - \pi_e^d(a)\right]^2$ and $2\left(\pi^d\right)^2$. Since $\pi_e^d(a) > 0$ for $a < a^{max}$, the result follows. The over-investments to partially deter co-investment with and without access obligations are, respectively, $2\left[\pi_1^d(a) + \pi_e^d(a) - 2\pi^d\right]^2$ and $2(\pi^m - 2\pi^d)^2$. The over-investment with access obligations is then lower if and only if $\pi_1^d(a) + \pi_e^d(a) \leq \pi^m$, which is true for all values of the fee. In particular, for $a = 0$, the condition reduces to $2\pi^d \leq \pi^m$; for $a \to a^{max}$, it holds that $\pi_e^d(a) \to 0$ and Assumption 1 guarantees that $\lim_{a \to a^{max}} \pi_1^d(a) \leq \pi^m$.

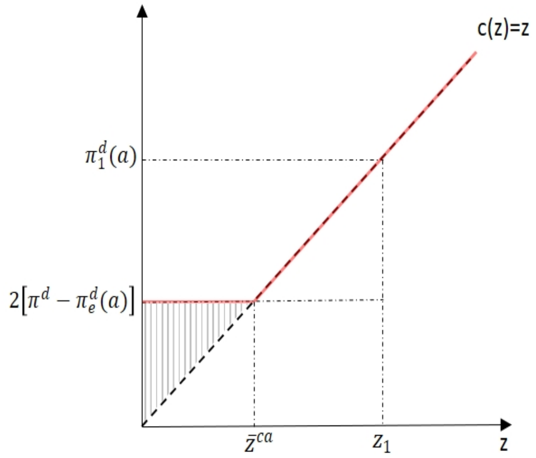

Fig. 2a. Complete co-investment deterrence
$3\pi^d - 2\pi_e^d(a) \leq \pi_1^d(a)$

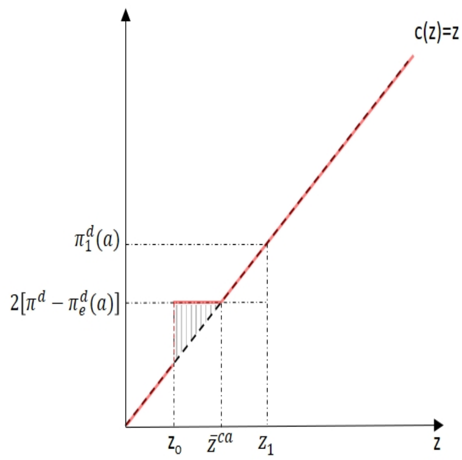

Fig. 2b. Partial co-investment deterrence
$2\pi^d - \pi_e^d(a) < \pi_1^d(a) < 3\pi^d - 2\pi_e^d(a)$

Analogously to the pure co-investment case, in any area z, the incumbent's gain from preventing co-investment is $\pi_1^d(a) - \pi^d$ and the cost of blocking co-investment is $\varepsilon_z + c(z)/2 = 2\left[\pi^d - \pi_e^d(a)\right] - c(z)/2$. The gain from preventing co-investment is greater than the corresponding cost in area z iff $\pi_1^d(a) - \pi^d \geq 2\left[\pi^d - \pi_e^d(a)\right] - c(z)/2$.

Complete co-investment deterrence ($3\pi^d - 2\pi_e^d(a) \leq \pi_1^d(a)$). Since the cost of blocking co-investment decreases with z, the incumbent finds it optimal to over-invest in areas $z \in [0, \bar{z}^{ca}(a)]$ iff $\pi_1^d(a) - \pi^d \geq 2\left[\pi^d - \pi_e^d(a)\right]$. In areas $z \in (\bar{z}^{ca}(a), z_1]$ there is no co-investment threat. Thus, complete deterrence occurs iff $\pi_1^d(a) \geq 3\pi^d - 2\pi_e^d(a)$. (See Figure 2a.)

Partial co-investment deterrence ($2\pi^d - \pi_e^d(a) < \pi_1^d(a) < 3\pi^d - 2\pi_e^d(a)$). Let $z_o \in (0, \bar{z}^{ca}(a))$ denote the area where co-investment deterrence starts. The incumbent's profit is

$$\Pi_1 = z_o\pi^d + (z_1 - z_o)\pi_1^d(a) - \int_0^{z_0} \frac{c(z)}{2} dz - (\bar{z}^{ca}(a) - z_o)2\left[\pi^d - \pi_e^d(a)\right] - \int_{\bar{z}^{ca}(a)}^{z_1} c(z)dz,$$

with $z_1 > \bar{z}^{ca}(a)$. The incumbent maximizes Π_1 with respect to z_o and z_1. Notice that $\partial\Pi_1/\partial z_o = \pi^d - \pi_1^d(a) - z_o/2 + 2\left[\pi^d - \pi_e^d(a)\right]$ is strictly positive at $z_o = 0$ iff $3\pi^d - 2\pi_e^d(a) > \pi_1^d(a)$: the incumbent thus allows co-investment in low cost areas. Optimally,

$$z_o = 2\left[3\pi^d - \pi_1^d(a) - 2\pi_e^d(a)\right],$$

and $z_1 = \bar{z}^a(a) \equiv \pi_1^d(a)$. Co-investment is not deterred in the areas $z \in [0, z_o)$ because it would be too costly, but it is in the intermediate areas $z \in [z_o, \bar{z}^{ca}(a)]$. Over-investments are not needed to deter co-investment in the areas $z \in (\bar{z}^{ca}(a), z_1]$. Notice that $z_o < \bar{z}^{ca}(a) < \bar{z}^a(a)$ since $2\pi^d - \pi_e^d(a) < \pi_1^d(a)$. (See Figure 2b.)

No deterrence ($\pi_1^d(a) \leq 2\pi^d - \pi_e^d(a)$). Over-investments are not optimal when $z_o \geq \bar{z}^{ca}(a)$, or equivalently, when $2\pi^d \geq \pi_1^d(a) + \pi_e^d(a)$.

Summarizing:

PROPOSITION 2 *With access obligations and co-investment:*

- *The incumbent over-invests to prevent any co-investment iff* $3\pi^d - 2\pi_e^d(a) \leq \pi_1^d(a)$ *(complete co-investment deterrence).*
- *The incumbent over-invests to prevent co-investment in the intermediate cost areas* $z \in [z_o, \bar{z}^{ca}(a)]$ *and allows co-investment in the low cost areas* $z < z_o$ *iff* $2\pi^d - \pi_e^d(a) < \pi_1^d(a) < 3\pi^d - 2\pi_e^d(a)$ *(partial co-investment deterrence).*
- *There is no over-investment whatsoever iff* $\pi_1^d(a) \leq 2\pi^d - \pi_e^d(a)$ *(no co-investment deterrence).*

With access obligations and co-investment, over-investments occur if and only if local industry profits without co-investment exceed those with co-investment: $\pi_1^d(a) + \pi_e^d(a) > 2\pi^d$. Absent access obligations, this condition reduces to $\pi^m > 2\pi^d$, which holds when the products are sufficiently close substitutes. In particular, with and without access, $\partial z_o / \partial \pi^d > 0$: the smaller π^d, the earlier over-investment starts; thus:

COROLLARY 1 *The amount over-invested is greater the closer substitutes the products are.*

Two remarks conclude the analysis:

- *Remark 1 - Total Coverage.* Allowing co-investment when access is already available does not impact the total coverage when $\bar{z}^{ca}(a) < \bar{z}^a(a)$, which holds whenever over-investments occur. Only in the region of no deterrence may co-investment boost coverage. Bourreau et al. (2018) argue that co-investment boosts coverage ($\bar{z}^{ca}(a) > \bar{z}^a(a)$) only when the access charge is high enough and the products are sufficiently differentiated since, for a close to $a^{\max}$, the condition $\pi_1^d(a) < 2\left[\pi^d - \pi_e^d(a)\right]$ tends to $\pi^m < 2\pi^d$. We determine that there are two subintervals in the no deterrence region: *(i)* $2\left[\pi^d - \pi_e^d(a)\right] < \pi_1^d(a) < 2\pi^d - \pi_e^d(a)$, where co-investment does not affect the total coverage, as in the deterrence regions; and *(ii)* $\pi_1^d(a) < 2\left[\pi^d - \pi_e^d(a)\right] < 2\pi^d - \pi_e^d(a)$, where co-investment increases the total coverage.
- *Remark 2 - Total Welfare.* Over-investments always reduce welfare. First, welfare decreases by the amount over-invested: unlike other investments (innovation or informative advertising, for example), this is a wasteful expenditure only aiming at blocking co-investment. Second, the market structure changes: without access, over-investments expand the monopoly areas; otherwise, they shrink the co-investment areas, which does not enhance welfare.[16]

[16] The model assumes that $w^d \equiv w^d(0)$ and $dw^d(a)/da \leq 0$, where $w^d(a)$ is the local welfare in a duopoly.

5 Numerical examples

Here we show that, for the numerical values considered in Bourreau et al. (2018, Appendix A), our model predicts that the incumbent partially deters co-investment. For comparison purposes, we follow their notation. The inverse demand function for firm $i = 1, e$ is $p_i = \alpha - \beta q_i - \gamma \beta q_j$, with $\alpha, \beta \geq 0$ and $\gamma \in (0, 1)$.[17] Firms compete in prices and direct demands are:

$$q_i = \frac{\alpha(1-\gamma) + \gamma p_j - p_i}{(1-\gamma^2)\beta}.$$

Both firms incur the local fixed interconnection cost f whenever they compete. Given the access charge, the incumbent's local profit is $\pi_1 = p_1 q_1 + a q_e - f$, whereas the entrant's local profit is $\pi_e = (p_e - a)q_e - f$,[18] with $a = 0$ when the entrant co-invests. Equilibrium prices are:

$$p_1 = \frac{(2-\gamma^2-\gamma)\alpha + 3a\gamma}{4-\gamma^2}$$

and

$$p_e = \frac{(2-\gamma^2-\gamma)\alpha + a\gamma^2 + 2a}{4-\gamma^2}.$$

We obtain the duopoly local profits by evaluating the equilibrium profits at $a = 0$:

$$\pi^d = \frac{(\gamma^2+\gamma-2)^2\alpha^2}{(\gamma^2-4)^2(1-\gamma^2)\beta} - f.$$

Considering the total deployment cost $C(z) = z^2/2$ and parameters $\alpha = \beta = 1$, the assumptions hold for $f = 0.12$ and $\gamma \in [0, 0.63]$.[19] Figure 3 plots the regions of Proposition 2 for (a) $\gamma = 0.25$, where $a^{max} = 0.195$, and (b) $\gamma = 0.5$, where $a^{max} = 0.083$. In both cases it holds that $2\pi^d - \pi_e^d(a) < \pi_1^d(a) < 3\pi^d - 2\pi_e^d(a)$ for all feasible a, then the incumbent finds it profitable to partially deter co-investment.[20]

[17] Inverse demand functions are derived from a representative consumer with quasi-linear utility.

[18] Marginal costs are assumed to be zero without loss of generality.

[19] That is, $\pi_e^d(a)$ decreases with a, $\pi_1^d(a)$ increases with a for all $a < a^{max}$, $\pi_e^d(a^{max}) = 0$, and $\pi_1^d(a^{max}) \leq \pi^m$.

[20] Consider $\gamma = 0.25$ and $a = 0.15$ for example, then $z_o = 0.10$, $\bar{z}^{ca} = 0.12$ and $z_1 = 0.14$; thus, co-investment is deterred in all areas $z \in [0.10, 0.12]$. Consider now $\gamma = 0.5$ with $a = 0.06$, then $z_o = 0.01$, $\bar{z}^{ca} = 0.04$ and $z_1 = 0.06$; thus, co-investment is deterred in all areas $z \in [0.01, 0.04]$.

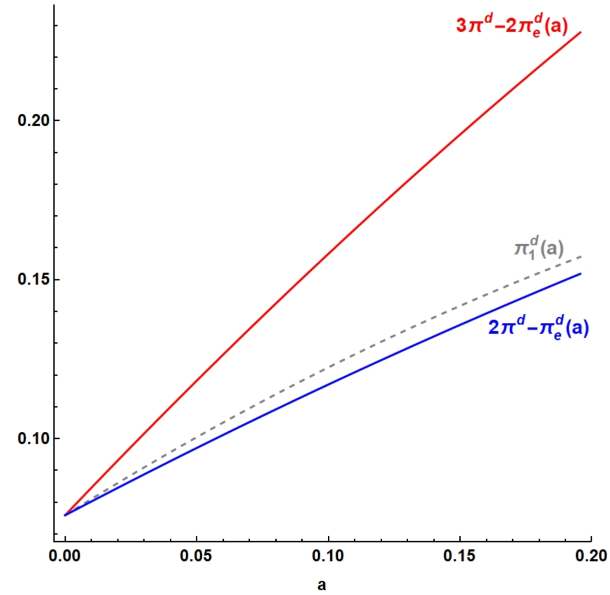

Fig. 3a. $\gamma = 0.25$.

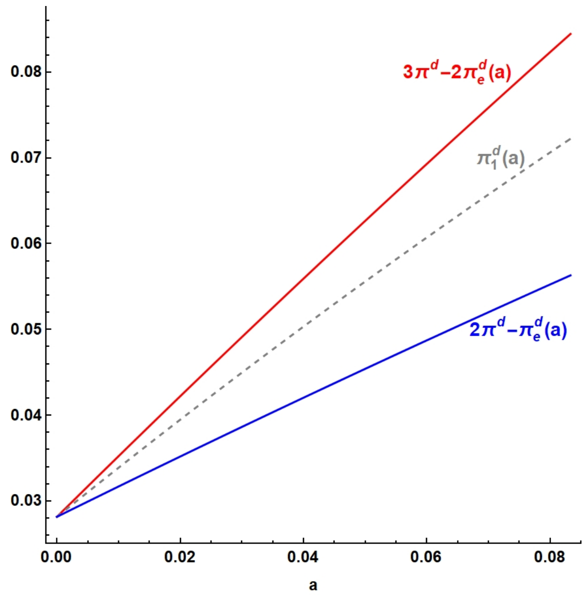

Fig. 3b. $\gamma = 0.5$.

6 Concluding remarks

In a context of new network deployment, we consider that the realized cost is verifiable but only the operators know the true deployment cost. Over-investments can then be used to deter co-investment, as the entrant refrains from co-investing for high enough realized costs and the regulator cannot identify the over-investment. We find that a necessary and sufficient condition for deterrence is that local industry profits are lower with than without co-investment. In the partial deterrence region, over-investments are non-monotonic and deterrence happens in the areas of intermediate attractiveness –deterrence would be too expensive where deployment costs are low, and unnecessary where deployment costs are high. The result is robust regardless of the availability of access obligations and/or the presence of demand uncertainty.

Since over-investing is optimal for an strategic incumbent and it decreases welfare, the authorities should take it into account when evaluating the welfare effects of different access pricing rules, such as the standard or the generalized efficient component pricing rules. Moreover, this deterrence possibility opens the more general question of the design of the optimal policy. It is also in our research agenda to explore the design of optimal mechanisms that eliminate the incentive to over-invest.

References

[1] Belleflamme, P., and Peitz, M. (2015). Industrial organization: markets and strategies. Cambridge University Press.

[2] BEREC (2016). Opinion on the European Commission's proposals for a review of the electronic communications framework. Document number: BoR (16) 213.

[3] BEREC (2020). Guidelines to foster the consistent application of the conditions and criteria for assessing co-investments in new very high capacity network elements (Article 76 (1) and Annex IV EECC). Document number: BoR (20) 232.

[4] Berkeley Research Group (2017). Co-Investment and Commercial Offers.

[5] Bourreau, M., Cambini, C., and Hoernig, S. (2018). Cooperative investment, access, and uncertainty. International Journal of Industrial Organization, 56, 78-106.

[6] Bourreau, M., Cambini, C., Hoernig, S., and Vogelsang, I. (2021). Co-investment, uncertainty, and opportunism: *ex-Ante* and *ex-Post* remedies. Information Economics and Policy, 56, 100913.

[7] Bourreau, M., Hoernig, S., and Maxwell, W. (2020). Implementing co-investment and network sharing. Centre on Regulation in Europe.

[8] Cabral, L. M. B. (2000). Introduction to industrial organization. The MIT press.

[9] Dafny, L. S. (2005). Games hospitals play: entry deterrence in hospital procedure markets. Journal of Economics & Management Strategy, 14(3), 513-542.

[10] Ellison, G., and Ellison, S. F. (2011). Strategic entry deterrence and the behavior of pharmaceutical incumbents prior to patent expiration. American Economic Journal: Microeconomics, 3(1), 1-36.

[11] Hart, O., and Moore, J. (1988). Incomplete contracts and renegotiation. Econometrica, 56(4), 755-785.

[12] Hermalin, B. E., and Katz, M. L. (1991). Moral hazard and verifiability: the effects of renegotiation in agency. Econometrica, 59(6), 1735-1753.

[13] Inderst, R., and Peitz, M. (2014). Investment under uncertainty and regulation of new access networks. Information Economics and Policy, 26, 28-41.

[14] Salop, S.C. (1979). New directions in industrial organization: strategic entry deterrence. American Economic Review, 69(2), 335-338.

[15] Spence, A.M. (1977). Entry, capacity, investment and oligopolistic pricing. The Bell Journal of Economics, 8, 534-544.