Modeling the regulatory uncertainty of NGA investments under cost-based access rules

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ABSTRACT

We study the impact of the regulatory uncertainty on the incumbents' incentives to invest in NGA networks under cost-based access rules. It is found that the incumbents underinvest unless they are compensated for the regulatory risk they incur in practice. The optimal risk premium that reflects the regulatory uncertainty is derived, as well as, its impact on the levels of NGA investment and competition. The main conclusion of this paper is that when the slope of the marginal cost function of the investment is significantly but not extremely steep, a cost-based access price that incorporates a markup for the demand uncertainty and a premium for the regulatory uncertainty leads to higher levels of both NGA investment and consumer surplus. Therefore, we show that, under plausible assumptions, the current regulatory practice in the European NGA market described by the EC Recommendation on regulated access to NGA can tackle the regulatory trade-off between encouraging efficient NGA investments and promoting effective competition.

Keywords: access regulation, competition level, investment incentives, regulatory uncertainty, telecommunications

JEL classification: L43, L51, L96

1. Introduction

The migration from the traditional copper networks to the Next Generation Access (NGA) networks[1] has induced a growing interest in access regulation and investment incentives. Given that the prospective investors in NGA networks are for large part the former incumbent operators (OPTA, 2010), the goal of regulators is to promote effective competition and encourage efficient and timely investments in NGA networks from the incumbents.

However, the regulators' two-fold goal is related to the common trade-off between static and dynamic efficiencies. On the one hand, mandated access at cost-based prices reduces the use of monopoly power over the access infrastructure by preventing the incumbent from foreclosing the entrant from the downstream (retail) market. Access regulation thus leads to sustainable service-based competition within one network and, hence, improves static efficiency (Valletti, 2003; Bouckaert, van Dijk and Verboven, 2010). On the other hand, mandating the access at cost-based prices discourages both incumbents and potential entrants to invest in access infrastructures (Jorde, Sidak and Teece, 2000). According to Cave and Prosperetti (2001), the reason for this negative relationship between access regulation and incumbents' incentives to invest is that the incumbents anticipate that they will be required to offer access to their rivals at cost-based prices. Therefore, potential entrants, who can free-ride on the incumbent's network, will wait for the incumbent to invest in access infrastructure and then seek access (Valletti, 2003). The conclusion is that cost-based access regulation, which is limited to promote service-based competition, leads to losses in dynamic efficiency (Bouckaert, van Dijk and Verboven, 2010).

Cambini and Jiang (2009) provide an excellent review of the theoretical and empirical literature on the relationship between broadband investment and regulation. They conclude that although cost-based access prices lead to the aforementioned regulatory trade-off, there is still an ambiguity about access regulation and its linkage with overall investment incentives that should be further investigated. In this direction, Siciliani (2010) proposes a mechanism for preventing regulatory failures stemming from the demand-side uncertainty. However, according to OPTA (2008), not only the uncertainty about future demand for new fibre-based services deters the incumbent from investing in NGA networks, but also the regulatory uncertainty related to the regulator's limited ability to make *ex ante* credible commitments.[2] Contrary to Siciliani (2010), we focus on the impact of regulatory uncertainty on the NGA investment level, which is one of the main open telecommunications policy issues worldwide. Since the regulators' goal is not only to encourage investments in NGA networks, but also to promote effective competition, the impact of regulatory uncertainty on the subsequent level of consumer surplus, which is used as a measure of the intensity of the competition in the retail market, will also be discussed.

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[1] According to EU Commission (2010) Next Generation Access (NGA) networks means wired access networks which consist wholly or in part of optical elements and which are capable of delivering broadband access services with enhanced characteristics (such as higher throughput) as compared to those provided over already existing copper networks. In most cases NGAs are the result of an upgrade of an already existing copper or coaxial access network.

[2] For an extensive review of all the factors influencing the riskiness of an NGA investment project, see ERG (2009), pp. 17-18, WIK (2009), pp.1-7 and EU Commission (2010), page 18.

2. Regulatory uncertainty: A literature review

The related literature provides two different approaches for studying the relationship between access regulation and the incumbent's incentives to invest in network upgrade (e.g. in NGA networks). The first assumes that the incumbents decide their optimal investment level prior to the regulation of the access price. This implies that the regulator cannot make *ex ante* credible commitments on its future interventions and hence the incumbents invest under regulatory uncertainty. Based on this assumption, Foros (2004) and Katakorpi (2006) study the investment of an incumbent in quality anticipating that the regulator will set the access price to the marginal cost of providing the access since this policy maximizes social welfare. They conclude that cost-based access price provides the incumbent with disincentives to invest unless it is much more efficient than its rivals in the downstream market. In addition, Lewin, Williamson and Cave (2009) argue that a lack of clarity over how incumbents will be regulated, particularly in terms of price when they have significant market power (SMP) in NGA supply, is deterring them from investing in NGA networks.

The second approach assumes that the regulation of the access price takes place prior to the incumbents' investment decision. According to Nitsche and Wiethaus (2010) and Valletti and Cambini (2005), this implies that there is no regulatory commitment problem. However, in fact, the regulator's *ex ante* commitment bears the risk of erroneous intervention. A regulator's commitment for a long regulatory period may result in either incumbents' inability of recouping their investment costs or excessive prices that harm competition. Therefore, it is socially not optimal for the regulator to make ex ante commitments for an unreasonably long regulatory period (WIK, 2009). It is obvious that short-run regulatory policies increase the regulatory uncertainty that the incumbents incur when investing in NGA networks. Therefore, in providing greater regulatory certainty the regulator has to make another trade-off between the positive effects of greater certainty on investment incentives and possible negative effects of erroneous intervention on welfare (OPTA, 2010).

As a result, even if the regulator sets the access price prior to the investment stage, the regulatory commitment problem still exists. This implies that both approaches make the incumbents reluctant to invest in NGA networks because of the regulator's limited ability to commit to its future intervention. Therefore, potential investors are reluctant to invest in NGA networks unless they are reimbursed for the risk they incur when investing in such networks. Based on this conclusion, the European Commission (EC) issued a Recommendation on regulated access to NGA (EU Commission, 2010) in order to provide the National Regulatory Authorities (NRAs) with guidelines for encouraging efficient and timely investments in NGA networks from the incumbents and promoting effective competition.

In particular, the EU Commission (2010) endorses the opinion of OPTA (2010) that *"from the perspective of an investor, uncertainty is only reduced when the regulators discloses intended regulatory intervention before the investment is made"*. Thus, the regulation of the access price is proposed to take place prior to the incumbents' investment decision. In addition the EC admits that regulatory certainty is a key factor to promote efficient investments by all operators. For this reason, the EC recommends calculating the access in a cost-based form that incorporates a risk premium. This premium should reflect any additional and quantifiable investment risk incurred by the investor.[3]

[3] See EU Commission (2010), Annex I.

The aim of this paper is to assess the risk premium that reflects the regulatory uncertainty according to the rules proposed by the EU Commission (2010). This implies that the access price should be cost-based incorporating a risk premium for the demand uncertainty and a risk premium that reflects the regulatory uncertainty. Sarmento and Brandao (2007) assume an access price equal to the marginal cost of providing the access plus the average cost of the investment. Such an access pricing formula is cost-based and we can assume that the access markup aims at reimbursing the investor for the demand uncertainty of NGA investments. We also use the access pricing formula proposed by Sarmento and Brandao (2007) but we allow for a risk premium that reflects the regulatory uncertainty.

The calculation of the regulatory risk premium is based on the comparison of the results obtained when the incumbent invests in network upgrade before and after the regulation of the access price. The first case has been already studied by Sarmento and Brandao (2007) who compare the impact of deregulation, cost-based regulation and retail-minus regulation on foreclosure, investment level and consumer surplus when the incumbent decides its optimal investment level prior to the regulation of the access price. On the contrary, we reverse the timing of the game assumed by Sarmento and Brandao (2007) in order to compare the results of the two approaches and to derive the risk premium that reflects the regulatory uncertainty of the investments in NGA networks under cost-based access rules. For the rest of the paper, we will call the approach of Sarmento and Brandao as “the incumbent’s approach” and our approach as “the regulator’s approach” since in the former case the incumbent acts as a leader in the market, whereas in the latter case the regulator acts as a leader and the incumbent as a follower.

It should be noted that, to best of authors’ knowledge, this is the first formal attempt to calculate the risk premium for the regulatory risks in a theoretical way.[4] The rest of the paper is organized as follows. Section 3 gives an outline of the basic assumptions and definitions of the model. Section 4 briefly recalls the results of Sarmento and Brandao (2007) under cost-based regulation. Section 5 studies the impact of cost-based regulation on competition and investments under “the regulator’s approach”, compares the results of the two approaches, calculates the risk premium and justifies regulatory implications. The last section summarizes the key findings of this paper.

3. The model

The aim of this paper is twofold. First, it aims to test the results of “the incumbent’s approach” under the assumption that the access price is set prior to the incumbent’s investment decision. Second, based on the comparison of the obtained results, it aims to calculate the risk premium that reflects the regulatory uncertainty of an investment in NGA networks. Since the obtained results should be comparable with those of Sarmento and Brandao (2007), the model used in this paper is identical to the model used by Sarmento and Brandao (2007) except of the timing of the game. In particular:

- The retail (downstream) market is characterized as an unregulated duopoly market in which the incumbent (the subsidiary firm of the upstream monopolist) acts as a

[4] OPTA (2010) has calculated a fixed premium of 3,5% for regulatory risks. However, we consider that this is the result of a techno-economic analysis since OPTA (2008) use such an analysis for deriving its optimal policy for regulating NGA investments.

Stackelberg leader and the entrant (the independent firm) act as a Stackelberg follower.

- The quality of the input sold by the monopolist is the same whether it is sold to the incumbent or to the entrant. It is also assumed that the production of one unit of the retail service requires one unit of the upstream input (fixed coefficients technology).
- The inverse demand function is given by $p = 1 + \beta I - (q_1 + q_2)$, where p is the retail market price, q_1 and q_2 are the quantities supplied by the incumbent and the entrant respectively, I represents the level of the NGA investment undertaken by the incumbent, and β represents the impact of a marginal change in the investment level on the retail price (ceteris paribus). It is further assumed that $\beta > 0$, which implies that an increase in the NGA investment level leads to an outward parallel shift in the demand that benefits both retailers.
- The NGA deployment is continuous where a larger I reflects a fibre deployment closer to the consumers' premises. The incumbent faces a quadratic NGA investment cost with respect to I, given by $c(I) = \varphi I^2/2$, with $\varphi > 0$. The convex form reflects the fact that fibre deployment becomes marginally more expensive as (i) it is being laid down towards consumers' premises, and/or (ii) it is extended to rural, less densely populated areas. It is further assumed that the NGA investment level does not have any impact on the (fixed) marginal cost of providing the access denoted by c, ($c < 1$). The access price that the entrant should pay to the incumbent in order to have access to the incumbent's network is represented by w, assuming $w \geq c$. The cost of all other inputs is equal for both retailers and normalized to zero. Therefore, the profits functions of the incumbent (firm 1) and the entrant (firm 2) are given, respectively, by

$$\pi_1 = (p-c)q_1 + (w-c)q_2 - \varphi I^2/2 \tag{1}$$

$$\pi_2 = (p-w)q_2 \tag{2}$$

- The timing of the game presented by Sarmento and Brandao (2007) is as follows:
  - First, the incumbent decides the investment level I.
  - Secondly, the regulator chooses the access price w.
  - Finally, the retail price and outputs of the firms are defined by Stackelberg competition between downstream firms.

  This paper provides an alternative approach by reversing the first two stages. Therefore, the timing of the game presented by this paper is as follows:

  - First, the regulator chooses the access price w.
  - Secondly, the incumbent decides the investment level I.
  - Finally, the retail price and outputs of the firms are defined by Stackelberg competition between downstream firms.

The backward induction technique is used to find the equilibrium of the whole game. Therefore, the analysis begins with the computation of the retail price and the outputs of the firms. Then, using these results, the incumbent's optimal investment level is obtained. Finally, based on the previous information, the optimal access price is derived.

4. The incumbent's approach

This section briefly recalls the results of Sarmento and Brandao (2007). In particular, each firm's output, total output and investment level under cost-based regulation are:

$$q_1^I = \frac{\varphi(1-c)(4+\varphi-\beta)}{2(4\varphi-\beta^2+\varphi^2-2\beta\varphi)} \tag{3}$$

$$q_2^I = \frac{\varphi(1-c)(2-\beta)}{2(4\varphi-\beta^2+\varphi^2-2\beta\varphi)} \tag{4}$$

$$q^I = \frac{\varphi(1-c)(6+\varphi-2\beta)}{2(4\varphi-\beta^2+\varphi^2-2\beta\varphi)} \tag{5}$$

$$I^I = \frac{(1-c)(\beta+\varphi)}{4\varphi-\beta^2+\varphi^2-2\beta\varphi} \tag{6}$$

Note that total output q^i, ($i = I, R$ with I and R denote the results obtained by the incumbent's and the regulator's approach, respectively), is a measure of competition since consumer surplus (*CS*) is given by $CS = (q^2)/2$. This implies that since the demand function is linear, a larger q^i leads to a larger CS.

5. The regulator's approach

Contrary to "the incumbent's approach", this section assumes that first the regulator sets the access price and then the incumbent chooses its optimal NGA investment level. In particular, this section initially provides the results obtained by an access pricing scheme that does not incorporate any risk premium (i.e. there is no regulatory commitment problem). Then, these results are compared with those obtained by "the incumbent's approach" in order to derive the risk premium that compensates the incumbent for the regulatory risk it incurs. Last, it provides the specific conditions under which the incorporation of a risk premium into the access price is beneficial for the consumers. If these conditions hold, the incorporation of such a risk premium into the access price is the optimal regulatory policy. If, on the contrary, these conditions do not hold, the regulatory policy should tackle the trade-off between encouraging NGA investments and promoting competition.

5.1. Access pricing without risk premium

Considering Stackelberg competition, the retail price and the output of the firms are the following:

$$q_1^R = (1+\beta I - c)/2 \tag{7}$$

$$q_2^R = (1+\beta I - 2w + c)/4 \tag{8}$$

$$P = (1+\beta I + 2w + c)/4 \tag{9}$$

Substituting Eqs. (7), (8) and (9) in (1) and taking the first order condition of Eq. (1) with respect to I, gives the NGA investment level that maximizes the incumbent's profits:

$$I^R = \beta(1+2w-3c)/(4\varphi-\beta^2) \quad (10)$$

Since $w \geq c$ and $c < 1$, the numerator of Eq. (10) is positive. Therefore, in order to guarantee that $I > 0$, the following assumption is made:

Assumption 1. Let $4\varphi - \beta^2 > 0$.

This assumption guarantees that φ is relative high, which means that the slope of the marginal cost function of the investment is significantly steep. It should be noted that this approach requires a lower φ than "the incumbent's approach" in order to guarantee that the NGA investment level is positive. The implication is that since φ and β are both exogenous factors, "the regulator's approach" leads to a positive investment level for more combinations of φ and β than "the incumbent's approach". However, for the rest of the paper, the assumption made by Sarmento and Brandao (2007) that $2\varphi - \beta^2 > 0$ also holds.

Considering the value of I^R, the retail price and the output of the firms are the following:

$$q_1^R = [2\varphi(1-c) + w\beta^2 - c\beta^2]/(4\varphi-\beta^2) \quad (11)$$

$$q_2^R = [\varphi(1+c) + w\beta^2 - 2w\varphi - c\beta^2]/(4\varphi-\beta^2) \quad (12)$$

$$P = [\varphi(1+c) + 2w\varphi - c\beta^2]/(4\varphi-\beta^2) \quad (13)$$

From Eqs. (10)-(13) it can be deduced that the NGA investment level, as well as, the output of the firms are affected by the access price w. This is an expected result since in "the regulator's approach" the regulator moves first and then the incumbent decides its optimal investment level.

Under cost-based regulation, the regulator defines the access price as the marginal cost of providing the access (c) plus a fraction (a) of the total investment cost, that is $w^R = c + aC(I)$, with $a < 1$. Like Sarmento and Brandao (2007), it is assumed that $a = (1/I)$, and hence, $w^R = c + (\varphi I/2)$. This definition implies that the regulator sets an access price equal to the marginal cost of providing the access plus the average cost of the investment.

Substituting $w^R = c + (\varphi I/2)$ in Eqs. (10)-(13) provides the final results under cost-based regulation:

$$q_1^R = \frac{\varphi(1-c)(4-\beta)}{2(4\varphi-\beta^2-\beta\varphi)} \quad (14)$$

$$q_2^R = \frac{\varphi(1-c)(2-\beta)}{2(4\varphi-\beta^2-\beta\varphi)} \quad (15)$$

$$q^R = \frac{\varphi(1-c)(3-\beta)}{4\varphi-\beta^2-\beta\varphi} \quad (16)$$

$$I^R = \frac{\beta(1-c)}{4\varphi - \beta^2 - \beta\varphi} \quad (17)$$

Assumption 2. Let $4\varphi - \beta^2 - \beta\varphi > 0$.

Assumption 2 is considered in order to ensure that $I^R > 0$. In addition, a necessary and sufficient condition for ensuring that both firms are active in the market (i.e. $q_1^R, q_2^R > 0$) is $\beta < 2$. Hence, the following assumption is made:

Assumption 3. Let $\beta < 2$.

The comparison of I^I and I^R shows that "the incumbent's approach" leads to higher investment level than "the regulator's approach".[5] Concerning consumer surplus, the comparison of the "regulator's" and the "incumbent's" approaches shows that the latter leads to a higher consumer surplus than the former if $3\beta > \varphi$.[6] Therefore, the consumers prefer the incumbent to decide prior to the regulation of the access price when the investment cost function is increasing and convex but not excessively convex in relation to the impact of the investment on demand. If, on the contrary, $3\beta < \varphi$, consumers would prefer the regulator to set the access price at cost before the incumbent decides its investment level. This is a reasonable result because the optimal investment is higher under "the incumbent's approach". Therefore, if the slope of marginal cost of the investment cost function is excessively steep in relation to the impact of the investment on demand, the incumbent's overinvestment is not socially desirable. Last, it is obvious that both approaches avoid foreclosure when the access is regulated at cost.

5.2. Discussion

The comparison of the results obtained by "the incumbent's approach" with those obtained by "the regulator's approach" shows that although it is ambiguous which approach leads to better results in terms of consumer surplus, "the incumbent's approach" leads to better results than "the regulator's approach" in terms of investment level.

This is an unexpected result since the obtained NGA investment level is higher under regulatory uncertainty than under credible regulatory commitments. The reason of this striking result is that although "the incumbent's approach" assumes regulatory uncertainty about the future regulatory policy, the incumbent undertakes such uncertainty by investing in NGA networks even if it is not reimbursed for such uncertainty. On the contrary, under no regulatory commitment problem, the optimal NGA investment level is lower because the incumbent does not undertake the regulatory uncertainty when it is not reimbursed for such uncertainty. It can be thus concluded that if the regulator announces a cost-based access price that incorporates a risk premium reflecting the regulatory uncertainty and then the incumbent choose its optimal NGA investment level, the derived level of the NGA investment will equal that of the "the incumbent's approach". We will call the former approach as "the regulator's approach with risk premium" since it assumes that the regulator first

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[5] See proof in Appendix A1.

[6] See proof in Appendix A2.

announces an access price scheme that compensates the incumbent for the regulatory uncertainty, and then the incumbent makes its optimal investment decision.

In the following section, we derive the risk premium that equates the investment levels obtained by "the incumbent's approach" and "the regulator's approach with risk premium" under cost-based access rules. The obtained risk premium reflects the regulatory uncertainty that the incumbent incurs when investing in NGA networks. Not surprisingly, "the regulator's approach with risk premium" leads to a higher investment level than "the regulator's approach". However, it should also lead to better results in terms of consumer surplus in order to be the chosen regulatory policy. Otherwise, there will be another regulatory trade-off between encouraging investments and promoting competition. Thus, we also provide the specific conditions under which the incorporation of a risk premium into the access price is beneficial for the consumers.

5.3. Access pricing with risk premium

This section studies the impact of the incorporation of a risk premium into the access price on investment level and total output. The risk premium should compensate the incumbent for its forgoing investments due to the regulatory uncertainty. As noted earlier, the risk premium that the regulator incorporates into the access price should equate the investment levels derived by "the incumbent's approach" and "the regulator's approach with risk premium". Or, in other words, the incumbent should be indifferent between investing prior or after the access regulation stage.

Under cost-based regulation with risk premium, the regulator defines the access price as in section 5.1. plus a premium over this access price. Then, $w^{RP} = (c + \varphi I / 2)(1 + y)$, where y represents the risk premium. Substituting this access price into Eq. (10) gives the incumbent's investment level as a function of y:

$$I^{RP} = \beta(1 - c + 2cy) / (4\varphi - \beta^2 - \beta\varphi - \beta\varphi y) \quad (18)$$

Equating I^{RP} with I^{I} and solving with respect to y gives the level of the optimal risk premium:

$$y = \frac{2\varphi^2(1-c)(2-\beta)}{\beta(\varphi^2 + c\varphi^2 + \beta\varphi + 8c\varphi - 2\beta^2 c - 5\beta c\varphi)} \quad (19)$$

Considering Eq. (19), the final results of the cost-based regulation with risk premium are the following:

$$q_1^{RP} = \frac{\varphi(1-c)(4-\beta+\varphi)}{2(4\varphi - \beta^2 - 2\beta\varphi + \varphi^2)} \quad (20)$$

$$q_2^{RP} = \frac{\varphi(1-c)(2-\beta)(\beta-\varphi)}{2(4\varphi - \beta^2 - 2\beta\varphi + \varphi^2)} \quad (21)$$

$$q^{RP} = \frac{\varphi(1-c)(3\beta + \beta\varphi - \varphi - \beta^2)}{\beta(4\varphi - \beta^2 - 2\beta\varphi + \varphi^2)} \quad (22)$$

$$I^{RP} = \frac{(1-c)(\beta+\varphi)}{4\varphi - \beta^2 + \varphi^2 - 2\beta\varphi} \quad (23)$$

Assumption 4. Let $4\varphi-\beta^2-2\beta\varphi+\varphi^2>0$.

Assumption 4 guarantees that the investment level under cost based regulation with risk premium is positive. Not surprisingly, this investment level is the same with the investment level obtained by "the incumbent's approach". For this reason, Sarmento and Brandao (2007) also make this assumption. In addition, a necessary and sufficient condition for ensuring that the entrant is active in the market is $\beta>\varphi$. If, on the contrary, $\beta\le\varphi$ the cost-based access regulation with risk premium forecloses the entrant from the downstream market. It is obvious that in this case the regulator should not incorporate into the access price such a high premium as y. For the rest of this section it is assumed that $\beta>\varphi$.

Therefore, the regulator should compare q^{RP} and q^{R} in order to decide whether or not the incorporation of a risk premium into the access price is the optimal policy. If the incorporation of risk premium leads to both higher investment level and total output, the regulator should set the access price at the level described by w^{RP}. The comparison of q^{RP} and q^{R} shows that the incorporation of y into the access price leads to higher total output (and then to higher competition level) if $\beta^2>\varphi$.[7] The regulatory implications of the analysis concerning the cost-based regulation can be summarized in the following proposition:

Proposition 1. *Under cost-based regulation, the optimal regulatory policy is: (i) to set the access price at* w^{RG} *if* $\varphi<\min\{\beta,\beta^2\}$*; and (ii) to set the access price at* w^{R} *if* $\varphi>\min\{\beta,\beta^2\}$.

From Proposition 1, it is deduced that the regulator should incorporate a risk premium into the access price when $\varphi<\min\{\beta,\beta^2\}$. This policy leads to higher investment level and consumer surplus than access price regulation without risk premium, while it ensures that the incumbent does not foreclose the entrant from the market. However, if $\beta\le\varphi<\beta^2$, "the regulator's approach with risk premium" results in both higher investment and consumer surplus level that the "the regulator's approach" but forecloses the entrant. In addition, if $\beta^2<\varphi<\beta$, there is a trade-off between encouraging investments and promoting competition. The reason is that a higher access price leads to a higher investment level and to lower consumer surplus. In these cases, a benevolent regulator whose primary goal is to enhance competition should set the access price at w^{R}. However, the benevolent regulator may also wait for the incumbent to undertake the risk of regulatory uncertainty if $\varphi<3\beta$. This implies that the incumbent invests before the regulation of the access price and such policy is optimal since it results in better outcomes that the "regulator's approach" in terms of both investment level and consumer surplus.

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[7] See proof in Appendix A3.

6. Conclusions

The aim of this paper was to derive the optimal risk premium that reflects the regulatory uncertainty incurred by investing in NGA networks. Thus, we compared the NGA investment levels obtained when the incumbent invests under regulatory certainty and under regulatory uncertainty.

When the incumbent chooses its optimal NGA investment level prior to the regulation of the access price which does not incorporate any risk premium reflecting the uncertainty about future regulatory intervention, it implicitly undertakes such risk since it chooses to invest. Therefore, although the incumbent invests under regulatory uncertainty, it does not take such uncertainty into account. Based on these assumptions, Sarmento and Brandao (2007) studied the impact of deregulation, cost-based regulation and retail-minus regulation on NGA investment level, consumer surplus and foreclosure of the entrant from the retail market. On the contrary, when the incumbent considers the regulatory uncertainty when determining its optimal NGA investment level, it chooses to invest after the regulation of the access price. We explored the robustness of the results of Sarmento and Brandao (2007) under the assumption that the incumbent invests in NGA networks after the regulation of the access at cost-based prices.

The comparison of the two approaches showed that cost-based regulation makes the incumbent underinvest if it considers the regulatory uncertainty when it deploys an NGA network. Therefore, the incorporation of a risk premium that reflects the regulatory uncertainty into the access price would make the incumbent choose the NGA investment level derived under regulatory uncertainty. We derived the risk premium that equates the NGA investment levels obtained by the approach of Sarmento and Brandao (2007) and the approach presented in this paper which incorporates a risk premium. Thus, the derived risk premium reflects the regulatory uncertainty of the investments in NGA networks.

However, it is widely known that the regulator's goal is not only to encourage efficient and timely investments in NGA networks, but also to promote effective competition. Thus, we also provided the condition under which the incorporation of a risk premium into the access price increases both NGA investments and competition. In particular, when the slope of the marginal cost function of the investment is significantly but not extremely steep (i.e. $\beta^2 > \varphi$), then a higher access price benefits both the incumbent and the consumers. Therefore, the incorporation of a risk premium into the access pricing formula is the optimal regulatory policy providing that it does not foreclose the entrant form the retail market.

It should be noted that the derived outcome is aligned with the current regulatory practice in the European NGA market since the access price reflects the cost of providing the access including a markup for the demand and the regulatory uncertainty of NGA investments. Therefore, we showed that, under plausible assumptions and specific conditions, cost-based access rules can tackle the regulatory trade-off between encouraging efficient NGA investments and promoting effective competition. However, the authors already study the impact of other regulatory instruments (such as deregulation and retail-minus regulation) on foreclosure, investment level and consumer surplus in order to compare their efficiency with that of cost-based regulation.

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Appendix A

We assume that regardless of the timing of the game, the investment level, the incumbent's output and the entrant's output are positive under cost-based regulation. Therefore:

A.1

The condition $I^I > I^R$ is equivalent to $I^I - I^R > 0$. From Eqs. (6) and (17) in the text, we have:

$$\frac{(1-c)(\beta+\varphi)}{4\varphi-\beta^2+\varphi^2-2\beta\varphi} - \frac{\beta(1-c)}{4\varphi-\beta^2-\beta\varphi} > 0 \Rightarrow$$

$$\frac{2\varphi^2(1-c)(2-\beta)}{(4\varphi-\beta^2-\beta\varphi)(4\varphi-\beta^2+\varphi^2-2\beta\varphi)} > 0$$

which always holds.

A.2

The condition $q^I > q^R$ is equivalent to $q^I - q^R > 0$. From Eqs. (5) and (16) in the text, we have:

$$\frac{\varphi(1-c)(6+\varphi-2\beta)}{2(4\varphi-\beta^2+\varphi^2-2\beta\varphi)} - \frac{\varphi(1-c)(3-\beta)}{4\varphi-\beta^2-\beta\varphi} > 0 \Rightarrow$$

$$\frac{\varphi^2(1-c)(2-\beta)(3\beta-\varphi)}{2(4\varphi-\beta^2-\beta\varphi)(4\varphi-\beta^2+\varphi^2-2\beta\varphi)} > 0$$

which holds for $3\beta > \varphi$.

A.3

The total output, q, is the sum of the incumbent's and the entrant's output, q_1 and q_2, respectively. Adding Eqs. (11) and (12) gives the total output as a function of the access price, i.e. $q^R = (3\varphi - \varphi c + 2w\beta^2 - 2w\varphi - 2c\beta^2)/(4\varphi - \beta^2)$. A marginal increase in w due to the incorporation of the risk premium causes a change in the total output by $2(\beta^2 - \varphi)$. Thus, if $\beta^2 > \varphi$, the incorporation of a risk premium into the access prices leads to higher total output and hence to higher consumer surplus (competition) level. In addition, the comparison of q^R and leads to the same result.

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