Access Regulation, Entry and Investments in Telecommunications*

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Abstract

This paper presents a model of competition between an incumbent and an entrant firm in telecommunications. The entrant has the option to enter the market with or without having preliminary invested in its own infrastructure; in case of facility based entry, the entrant has also the option to invest in the provision of enhanced services. In case of resale based entry the entrant needs access to the incumbent network. Unlike the rival, the incumbent has always the option to upgrade the existing network to provide advanced services. We study the impact of access regulation on the type of entry and on firms' investments. We find that without regulation the incumbent sets the access charge to prevent resale based entry and this generates a social inefficient level of facility based entry. Access regulation may discourage welfare enhancing investments, thus also inducing a socially inefficient outcome. We extend the model to account for negotiated interconnection in case of facilities based entry.

Keywords: telecommunications, ladder of investment, access regulation, interconnection.
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1 Introduction

The development of competition between infrastructured operators is usually seen as the ultimate goal in the broadband market. Regulation of access, namely the determination of the conditions for entrant firms to access the network controlled by the incumbent, is often considered as the crucial element to achieve this goal. In this respect, many national regulatory authorities across Europe seem to have embraced a regulatory approach based on the so called "ladder of investment" theory, introduced by Cave and Vogelsang (2003). According to this approach, regulators should encourage access to wholesale markets by fixing very low access prices, particularly for the network elements that are too expensive for new entrants to replicate. As soon as new entrants consolidate their market positions, authorities should increase access prices to these network elements in order to encourage entrants to invest and to create gradually their own infrastructure, to move up the ladder of investment in the industry jargon.

Despite this regulatory approach appears to have largely influenced the action of European regulators,[1] the economic literature on the relation between access regulation and firm's investments in telecommunications is still lagging behind.[2] The urge for a theoretical analysis providing guidance and suggestions on these crucial issues is also reinforced by the fact that, nowadays, new access technologies have made much more affordable the deployment of alternative access networks (See Reichl and Ruhle, 2008).[3]

Obviously, not only entrant firms may develop their infrastructures to offer next generation services, but also the incumbent, which is usually already in control of a physical network, has the option to upgrade its infrastructure to supply advanced communications services. In this paper we propose a theoretical model that accommodates this scenario. In particular, we model competition between an incumbent and an entrant firm where both op-

[1]A preliminary empirical analysis of the ladder of investment is in Distaso et al. (2009) where the authors test whether entrants have effectively climbed the rungs of the ladder of investments in 12 European countries; they show that in the period 2005-07 the policies adopted by National Regulatory Authorities have been broadly consistent with this regulatory approach. Notably, Friederiszick et al. (2008) reach a different conclusion; by using a panel of 180 telecom firms in 25 European countries, they show that pro-entry regulation seems to have discouraged entrants investments in fixed-line telecommunications. For a critical review of the ladder of investment approach see Bourreau et al. (2010).

[2]For a recent and exhaustive survey on broadband investments and regulation see Cambini and Jiang (2009).

[3]In Europe, Italy represents a good example of this technological evolution: in May 2010 the three main rivals of Telecom Italia, the incumbent operator, Wind, Fastweb and Vodafone have announced their intention to start building their fibre optic network, an infrastructure alternative to that of the incumbent.

erators may invest in the provision of next generation services before retail competition takes place. Until the alternative network has not been deployed, the entrant needs access to the incumbent infrastructure to operate and this justifies the intervention of a social maximizing regulator aimed at determining the access conditions to the incumbent's network.

More specifically, following the aforementioned ladder of investment theory, we consider a scenario in which an entrant operator may decide to enter the market with or without its own access network (facility based entry *vs* service based entry); in the former case, the rival does no longer need access to the incumbent infrastructure to operate. On the top of that, once it has deployed its infrastructure, the entrant is in the position to invest in advanced broadband technologies to offer enhanced communications services (i.e. high speed broadband) to its customers. The incumbent independently of the entry decision by the rival, has always the option to invest in advanced services by upgrading the existing infrastructure currently under its control; this implies that in our model, operators investments in enhanced services have a strategic nature.

We study the impact of access regulation on the type of entry and on the amount of firms' investments. By setting a low access charge, the regulator stimulates service based entry but this may have negative effects on the amount of investments in advanced services. We discuss the properties of access regulation and we show that under certain conditions, regulator's activity may go to the detriment of social welfare. The comparison between the equilibrium outcomes with and without regulation is useful to highlight these regulatory failures and to disentangle them from market failures.

These analyzes are made under the implicit assumption of cost based interconnection where, in case of facilities based entry, the incumbent and the entrant operators interconnect their infrastructures at marginal cost. This is only one of the possible forms of interconnection between competing infrastructures that are currently under scrutiny; the other most common interconnection scheme is bilateral access, where firms negotiate a common interconnection charge. In the last part of the paper we evaluate how equilibrium outcomes change when firms negotiate on a reciprocal term of access.

Our model builds upon several papers that have been focussing on the relationship between access regulation and entry in telecommunications. Brito et al. (2010) model competition between a vertically integrated incumbent and a downstream entrant requiring access to the incumbent's network. The authors develop a model where only the incumbent is allowed to sink a fixed amount of investment in order to deploy a next generation network[4]

[4]Notably, in another version of the model, the authors extend their framework to encompass the case of the entrant deploying its infrastructure; they show that if the investment cost is large, the possibility of both

and compare two regulatory regimes, one with a regulator that can commit to an access policy towards the new network before the incumbent has made its investment, and one in which the regulator cannot; the authors show that when the regulator sets a two-part access charge, the availability of two regulatory instruments (i.e. the two parts of the non linear tariff) may allow the regulator to solve the usual trade-off between static efficiency (reduce incumbent's marker power) and dynamic efficiency (stimulate incumbent's investments).

Another paper which is closely related to the ours is Avenali et al. (2010). The authors analyze the impact of access price regulation on the entrants' decision to enter where the entrant has the option to invest in enhanced services. Interestingly, in a two-period game, they show that an access charge that rises over time fosters infrastructure investment by the entrant, a regulatory behavior consistent with the ladder of investment theory. Brito et al. (2010) and Avenali et al. (2010) analyze the two polar cases where either the incumbent or the entrant invest in new infrastructures. In this paper we follow a more realistic scenario and we allow both the firms to invest in enhanced services; more specifically, we distinguish between two forms of investments: the construction of a new infrastructure and the investments in enhanced services.

Foros (2004) is also particularly relevant to our analysis. In a framework where only the incumbent invests and where firms competing on the retail market are assumed to be heterogenous in their technical efficiency, the author shows that access price regulation, with no commitment by the regulator, may reduce welfare if the efficiency of competing firms technologies do not differ too much. Moreover, the incumbent firm may overinvest to foreclose the market. From Foros (2004) we borrow the demand structure affected by firms' investments in value added services; thanks to these investments, firms supply services valuable to their customers and that generate also a positive spillover to the whole economy; in this framework, we concentrate on the effects of the entrant decisions to enter on the incumbents' investments in value added service.

Finally, despite they do not model investments in enhanced services, our paper also relates to Bourreau and Dogan (2005) and Bourreau and Dogan (2006). Both these papers study the decision to enter of a rival operator in a dynamic context. In the former, the two authors focus on the effect of multi-period access pricing on the "make or buy" decisions of an entrant; they show that the incumbent tends to set too low the access price and this

firms investing never improves social welfare (Brito et al., 2008). They model a framework which is rather different from ours, being investments decisions a discrete choice which imply a fixed cost of deployment. Furthermore, and unlike in Brito et al. (2010), they assume that in case the incumbent rolls out its new network, the old infrastructure is still in place and the entrant can still gain access to it.

induces the entrant to roll out its network too late from a social welfare perspective. In the latter paper, the authors go even further on these issues but they ignore the role of regulation.

The rest of the paper is organized as follows: in section 2 we present the model assuming Bill & Keep interconnection in case of facilities based entry. In section 3 we extend the model allowing for negotiated bilateral interconnection charges and Section 4 concludes.

2 The Model

Telecommunications services are offered by two firms: an incumbent, denoted by I, and an entrant firm, denoted by E. The incumbent is not only active at the retail level, but it also controls and manages an upstream infrastructure, the access network, that may represent an essential input for an entrant firm.

E may enter the market in two ways: with or without having preliminary built its own infrastructure;[5] in the latter case, E needs access to I's network to operate and, in case of entry, retail competition takes the form of "service based" competition. Alternatively, after having sunk a given amount $F > 0$ of resources, E can roll out its own infrastructure which allows the entrant to operate without the need to access I's upstream network; retail competition is said to be "facilities based" in this case. In the baseline model, the two infrastructured operators are assumed to interconnect their networks free of charge.

Before final production takes place, each infrastructured operator can undertake an investment $C(x_i)$ to upgrade its network in order to provide qualitatively superior services (e.g. high speed access broadband, etc), where x_i represents the quality of the services offered by operator i. Note that while the incumbent is always in the position to invest in advanced communications technologies, E can undertake such investments only provided that it has entered the market with its own infrastructure.

This way of modelling entrant's and incumbent's investments in advanced services has a natural interpretation when looking at the cost of rolling-out a next generation network (NGN). In fact, the cost of deploying a NGN for an alternative operator is largely associated to the cost of trenching and ducting; on top of these civil/engineering costs, the operator invests in "quality" by choosing the preferred technology of transmission (VDSL, fibre, etc).

[5] We model E as a new entrant; equivalently, E could have been modelled as already active in the market as a pure reseller, with its current profits normalized to zero; according to this interpretation, E's decision should have been about wether to remain a service based competitor seeking access through unbundling to the existing infrastructure or to move up the investment ladder by building its own network.

Incumbents are far better placed than alternative operators to invest in NGN: they rely on the availability of the vast majority of network elements needed to deploy a NGN (ducts, fibre, street cabinets) and they can also enjoy revenues from dismantling unused elements and selling their respective locations.[6] For simplicity, in our model we normalize to zero the incumbent fixed cost of deploying a NGN; therefore while the incumbent upgrades its network by investing $C(x_I)$ in service quality, the entrant has to sink preliminary the fixed amount F to cover ducting and trenching costs. Hence, in this stylized framework, F can be reinterpreted as the entrant's cost disadvantage with respect the incumbent in the provision of advanced services.

This structure of investments in enhanced services is consistent with the so called "ladder of investment" theory, a regulatory approach initially proposed by Cave and Vogelsang (2003) - and then refined in Cave (2006) - that has largely influenced European regulators. Despite this theory has been proposed to describe unbundling and access pricing regulation in traditional broadband, in Cave (2010) is shown that an equivalent ladder exists with NGNs.[7] According to this view, entrants' investments in telecommunications occur following a sequential process: new comers first invest in the network elements that are easier to replicate and, once gained market shares and knowledge, they may decide to "climb" the ladder of investment by replicating also the other parts of the network. The last step is reached when entrants build their own alternative network; this allows them to offer advanced services without the need to access the incumbent's network.

The timing of investments is described in Figure 1, where $b = \{0, 1\}$ indicates E's entry decision: b=0 if entry occurs without infrastructure and b=1 otherwise; x_I and x_E denote the investments in value added services made by the incumbent and the entrant, respectively.

The pattern of the investments affects the demand's structure. In fact, by investing $C(x_i)$, the infrastructured operator i is able to offer value added services of quality x_i; customers are willing to pay a higher price for these services and following Foros (2004), we represent this as an upward shift in the demand function faced by the firm.[8] Furthermore, the investment may have a positive effect also on the demand schedule faced by the rival (positive spillover). This spillover may have different sources. Consider two firms that are competing in the

[6] For details about the costs of rolling out a next generation network see Elixmann et al. (2008).

[7] The European Regulatory Group also shares the opinion that, although more sophisticated, a ladder of investment still exists in a NGN environment; see ERG (2007) for details.

[8] Once firms have upgraded their infrastructures, all customers benefit from the better quality of the services provided. In the NGN interpretation of our model, this is equivalent to assume that the old infrastructure is switched-off as long as the new networks have been rolled out; as a consequence, once invested, firms provide only enhanced services.

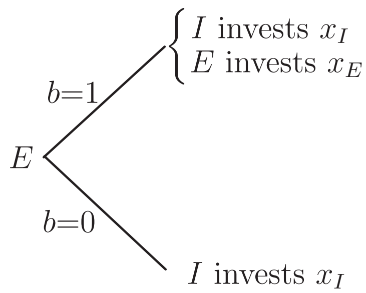

Figure 1: the dynamic structure of the investments

market for access to the internet, where the investment in firm i's physical network allows the firm to offer higher Quality of Services (QoS in the industry jargon); in this case, the better the quality of services on network i, the better the quality also enjoyed by firm j's customers when they download content from sites hosted on i's network. Alternatively, a higher QoS by firm i stimulates the provision of new and more advanced on-line services that go to the benefit also of firm j's customers.

Formally, we model the demand functions faced by the incumbent and the entrant as follows:

$$P_I|_{b=0} = A + \beta x_I - q_I - q_E, \qquad P_E|_{b=0} = A + \mu x_I - q_I - q_E,$$

in case of service based entry (b=0), where q_i is the amount of output produced by firm i; alternatively, in case of facilities based entry (b=1), both firms may invest in value added services and the demand functions are:

$$P_I|_{b=1} = A + \beta x_I + \mu x_E - q_I - q_E, \qquad P_E|_{b=1} = A + \beta x_E + \mu x_I - q_I - q_E.$$

$\beta \in [0, 1]$ represents the own demand effect of the investment in value added services, and $\mu \in [0, \beta]$ the spillover effect.[9] It is natural to assume that $\mu \leq \beta$, namely that the spillover cannot be larger than the effect generated by own investments.

When the entrant decides to enter without having preliminary invested in its own infrastructure, it needs access to I's network; we denote with a the access charge that E pays to I for each unit of output sold to customers.

We are now able to define I's and E's profit functions. Given the demand functions, when

[9]We are implicitly assuming that I and E have the same ability in exploiting the investments; this may not be generally true since both the own demand effect and the spillover effect might differ across firms. For the sake of model's tractability we do not take this into account.

E enters without infrastructure, incumbent's and entrant's profits are respectively given by:

$$\Pi_I|_{b=0} = (A + \beta x_I - q_I - q_E - c_o - c_I)q_I + (a - c_o)q_E - C(x_I), \quad (1)$$

and

$$\Pi_E|_{b=0} = (A + \mu x_I - q_I - q_E - a - c_E)q_E, \quad (2)$$

where c_o represents the upstream marginal cost faced by the incumbent, c_i, $i = I, E$, the cost at the retail level faced by firm i and $C(x_I)$ the investment in value added services incurred by the incumbent. In expression (1), the term $(a - c_o)q_E$ represents the access revenues enjoyed by the incumbent which is proportional to q_E, the entrant's output.

Alternatively, if E enters with its own infrastructure, I's and E's profits are respectively given by:

$$\Pi_I|_{b=1} = (A + \beta x_I + \mu x_E - q_I - q_E - c_o - c_I)q_I - C(x_I), \quad (3)$$

and

$$\Pi_E|_{b=1} = (A + \beta x_E + \mu x_I - q_I - q_E - c_o - c_E)q_E - C(x_E) - F, \quad (4)$$

where F and $C(x_E)$ represent E's fixed cost of rolling out the alternative infrastructure and its investment in value added services, respectively. Note that whenever the entrant enters the market with its own facilities, it does no longer need access to I's infrastructure and, consequently, the incumbent does not receive any access revenues.

For the sake of simplicity, all through the paper we normalize to zero the marginal costs of production: $c_I = c_E = c_o = 0$. Finally, we assume quadratic cost functions in the investments in advanced services: $C(x_i) = x_i^2/2$.

One of the crucial ingredients of our model is the determination of a, the access charge payed by E to I whenever the entry regime b=0 occurs. The access charge can be either regulated or unregulated. In case of access regulation, the regulator sets a at the welfare maximizing level; in order to rule out the possibility of access subsidization, we always assume that the regulator cannot set the access charge below the cost of providing access, formally $a \geq 0$. We model two regulatory regimes: *i*) access regulation without commitment and *ii*) access regulation with commitment. In the latter case, the regulator intervenes before firms have taken their investments decisions and she finds a way to keep this regulatory decision afterwards; in the former case the regulator is unable to commit to a long run decision and sets a only once I and E have already invested. The distinction between these two regimes is relevant since, as discussed above, the ladder of investment theory is essentially a regulatory regime where the regulator commits herself to adhere to a predetermined pattern in the access charge.

Therefore, we model three possible scenarios concerning the determination of the access charge:[10]

1. unregulated access, whereby a is set by the incumbent;
2. access regulation without commitment, whereby the regulator sets the socially optimal access charge after having observed I's and E's investments behavior;
3. access regulation with committed regulator, whereby the regulator sets the socially optimal access charge before firms undertake their investments.

2.1 Unregulated access

When the access charge is unregulated, the terms of access are set by the incumbent firm. We solve the model by backward induction; let us start from the last stage of the game, namely the competitive stage where I and E compete a' la Cournot in the retail market. If E has entered with its own infrastructure (b=1), the incumbent and the entrant set, respectively, q_I and q_E in order to maximize their respective profits given in (4). Cournot outcomes are therefore:

$$q_i|_{b=1} = \frac{A + x_i(2\beta - \mu) - x_j((2\mu - \beta)}{3}, \quad i = I, E. \tag{5}$$

Substituting these expressions back into the profit functions and maximizing these latter with respect to x_I and x_E it is immediate to obtain the optimal amount of investments in enhanced services by the two firms:[11]

$$x_I^*|_{b=1} = x_E^*|_{b=1} = \frac{2A(2\beta - \mu)}{G(\beta, \mu)}. \tag{6}$$

where $G(\beta, \mu) = 9 - 2(\beta + \mu)(2\beta - \mu)$, with $G(\beta, \mu) > 0$. Finally, using all these expressions, firms' profits with facilities based entry are as follows:

$$\Pi_I^*|_{b=1} = \frac{A^2(9 - 2\,(2\,\beta - \mu)^2)}{G^2(\beta, \mu)}, \quad \text{and} \quad \Pi_E^*|_{b=1} = \Pi_I^*|_{b=1} - F. \tag{7}$$

[10]Note that there might be also a fourth scenario, namely unregulated access with commitment, whereby the incumbent commits to adhere to a predetermined level of a before firms undertake their investments. While, as discussed in the paper, the adoption of a regulatory mechanism based on the ladder of investment represents the practical justification for the scenario of access regulation with a committed regulator, the case of committed incumbent is practically irrelevant; for this reason we have decided to omit this case from the analysis.

[11]The second order conditions are satisfied.

Let us now consider the alternative case of service based entry, b=0. In this case, for any unit of output sold, the entrant pays the incumbent the access charge; using the profit functions given in expressions (1) and (2), it is possible to derive the optimal output sold by the two firms as a function of a:

$$q_I|_{b=0} = \frac{A + (2\beta - \mu)x_I + a}{3}, \quad \text{and} \quad q_E|_{b=0} = \frac{A - (\beta - 2\mu)x_I - 2a}{3}. \tag{8}$$

As expected, the quantity produced by the entrant decreases with the access charge. It is possible to verify that incumbent's profits are monotonically increasing with a; as a consequence, if the incumbent is left free to set the access charge, it will set a at the highest possible level, namely the level that drives the entrant out of the market. Formally, I sets a such that $q_E|_{b=0} = 0$. Using expressions (8):

$$a^{ur} = \frac{A - (\beta - 2\mu)x_I}{2},$$

where the superscript ^{ur} indicates that we are in the unregulated scenario. Going back to the first stage, the optimal level of enhanced investments undertaken by the incumbent when it charges a^{ur} is given by $x_I^{*ur}|_{b=0} = A\beta/(2-\beta^2)$ and incumbent's profits would be simply given by $\Pi_I^{*ur}|_{b=0} = A^2/(2(2-\beta^2))$, i.e. the monopoly level.

An interesting observation emerges from a comparison between the industry wide amount of investments with and without entry:

Lemma 1. *If the spillover is sufficiently large, industry-wide amount of investments in enhanced services in case of facilities based entry is lower than the amount of investments undertaken by a monopoly; formally, if* $\mu > \kappa(\beta)$[12] *then* $x_I^*|_{b=1} + x_E^*|_{b=1} < x_I^{*ur}|_{b=0}$*; when* $\mu < \kappa(\beta)$*, the opposite occurs.*

Lemma 1 will turn out to be useful later in the paper. The motivation for this result goes as follows: each firm benefits, at least to a certain extent, from the investment made by the rival due to the spillover effect; the stronger the spillover, i.e. the closer μ is to the private value generated by the investment β, the more investments in enhanced services have the typical nature of a public good. In this case, firms behave opportunistically and the industry-wide amount of investments suffers of under-provision; on the contrary, when the private value generated by the investment is large and the spillover effect is weak, firms free ride less on each other investment and industry-wide investments with facility based entry tend to be larger.

[12] Where $\kappa(\beta) = \frac{3\beta^2 - 4 + \sqrt{(\beta^2-2)(\beta^2-8)}}{2\beta}$.

From expressions (7), it emerges immediately that E enters and invests in its own infrastructures only if $F \leq F^{ur}$, where

$$F^{ur} = \frac{A^2(9 - 2\,(2\,\beta - \mu)^2)}{G^2(\beta, \mu)}. \tag{9}$$

This result is well known in the economic literature.[13] The incumbent uses the access charge to deter service based entry; E may, eventually, enter only after having built its own network: only facilities based entry may occur and this is actually going to happen only when the cost of the investment F is not too large.

It is now useful to determine the equilibrium level of welfare, W. Following standard arguments, we measure W as the sum of the consumers' and producers' surpluses; formally: $W = CS_I + CS_E + \Pi_I + \Pi_E$, where CS_I and CS_E represent the total surplus enjoyed by I and E consumers' respectively. In case of facilities based entry, these surpluses are defined as:

$$CS_i|_{b=1} = \frac{1}{2}(A + \beta x_i + \mu x_j - P_i|_{b=1})q_i, \quad \text{with} \quad i, j = I, E.$$

Using the equilibrium expressions $x_i^*|_{b=1}$, $q_i^*|_{b=1}$ and $\Pi_i^*|_{b=1}$, it is possible to derive the level of surplus enjoyed by the society in this case as a function of the fixed cost of entry, F:

$$W^*|_{b=1} = \frac{4A^2(2\beta - \mu + 3)(2\beta - \mu - 3)}{G^2(\beta, \mu)} - F. \tag{10}$$

In case of service based entry, the general expression of the welfare function defined as the sum of consumers and producers surpluses is given by:

$$W|_{b=0} = \frac{(A + \beta x_I - P_I|_{b=0})q_I}{2} + \frac{(A + \mu x_I - P_E|_{b=0})q_E}{2} + P_I|_{b=0}q_I + P_E|_{b=0}q_E - \frac{x_I^2}{2}. \tag{11}$$

This expression does not depend on a; in fact, the access charge represents a mere transfer from the entrant to the incumbent, without any direct effect on the level of welfare; obviously, a indirectly impacts on the quantities sold by the two firms and on the amount of investments. Using the equilibrium outputs and the amount of investments derived above for the case $b = 0$, the level of welfare associated to this case is given by :

$$W^{*ur}|_{b=0} = \frac{A^2(3 - \beta^2)}{2(2 - \beta^2)^2}. \tag{12}$$

Since the unregulated incumbent sets a to foreclose the market, $W^*|_{b=0}$ is the level of welfare enjoyed under monopoly.

[13] Among others, see Avenali et al. (2010).

From our previous analysis we know that at the equilibrium without access regulation, only infrastructured entry may eventually occur and this happens if $F \leq F^{ur}$; a comparison between the welfare levels in the two scenarios with and without entry given in expressions (10) and (12) reveals some interesting aspects of the equilibrium. While the equilibrium social welfare with facilities based entry, $W^{*}|_{b=1}$, decreases with the entrant fixed cost of rolling out the network, the welfare in case of service based entry, $W^{*ur}|_{b=0}$, does not depend on F, provided that for $b = 0$ the entrant does not invest. Hence, it is possible to define a threshold level $\tilde{F}^{ur}$ as the level of the entrant's fixed cost such that $W^{*ur}|_{b=0} = W^{*}|_{b=1}$; formally:

$$\tilde{F}^{ur} = \frac{A^2 H(\beta, \mu)}{2G^2(\beta, \mu)(\beta^2 - 2)^2}.$$

where

$$H(\beta, \mu) = 16\beta^5(3\mu - \beta) - 20(\mu^2 - 4)\beta^4 - 4\mu(53 + 2\mu^2)\beta^3 + (4\mu^4 - 119 + 104\mu^2)\beta^2 + 4\mu(6\mu^2 + 59)\beta + 4\mu^2(35 + 3\mu^2) + 45.$$

By definition, whenever $F > \tilde{F}^{ur}$, social welfare is higher under monopoly then with facilities based competition ($W^{*ur}|_{b=0} > W^{*}|_{b=1}$) and the opposite for $F < \tilde{F}^{ur}$. A comparison between F^{ur} and $\tilde{F}^{ur}$ reveals that without regulation entry may be socially inefficient; the following lemma compares $\tilde{F}^{ur}$ with F^{ur} and it helps to qualify the various forms of inefficiencies:

Lemma 2. *If access charge is not regulated, there exists a subset M of pairs (μ, β) such that $\tilde{F}^{ur} > F^{ur}$ if $(\mu, \beta) \in M$, while $F^{ur} > \tilde{F}^{ur}$ if $(\mu, \beta) \notin M$.*

Proof. To prove the Lemma, define $\Delta(\mu, \beta) = F^{ur} - \tilde{F}^{ur}$. It is possible to verify that the condition $\Delta(\mu, \beta) = 0$ generates a partition of two blocks of the set $[\mu X \beta]$, with $0 < \mu \leq \beta \leq 1$. □

According to this Lemma, two forms of inefficiencies may emerge, depending on parameters' values. The following Proposition characterizes the two scenarios:

Proposition 1. *Without regulation of the access charge, entry may be socially undesirable; in particular:*

1. *if $(\mu, \beta) \in M$ and $F \in (F^{ur}, \tilde{F}^{ur})$ entry does not occur but the social welfare would be higher with entry (lack of entry);*

2. *if $(\mu, \beta) \notin M$ and $F \in (\tilde{F}^{ur}, F^{ur}]$, entry occurs but the social welfare would be higher without entry (inefficient entry).*

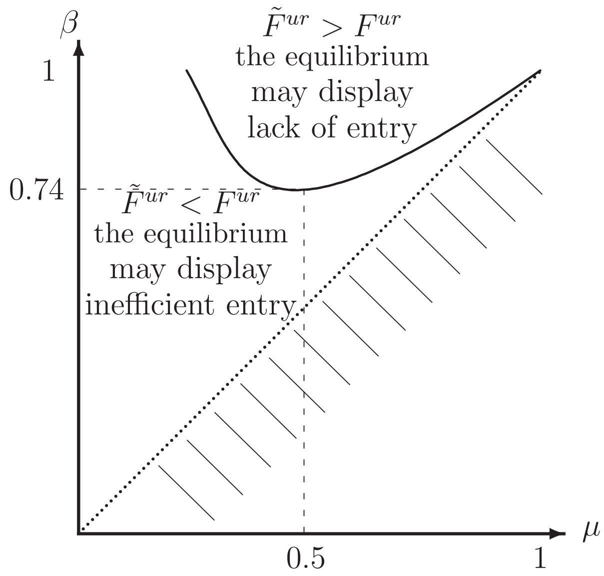

Figure 2: market inefficiencies

This Proposition highlights the two possible forms of inefficiencies that may arise when the entrant actually decides to enter and to invest in advanced services; Figure 2 is useful to interpret the Proposition. The parabola drawn in the diagram represents the set of pairs (μ, β) such that $F^{ur} = \tilde{F}^{ur}$: the region above the parabola is the subset M defined in Lemma 2, where $\tilde{F}^{ur} > F^{ur}$. Any time the entrant's cost of rolling out the infrastructure falls in between the two threshold levels, market forces may lead to a socially inefficient outcome; which type of inefficiency actually occurs depends on whether $F^{ur} > \tilde{F}^{ur}$ or $F^{ur} < \tilde{F}^{ur}$. Suppose that $(\mu, \beta) \notin M$ (hence $F^{ur} > \tilde{F}^{ur}$) and that $F \in (\tilde{F}^{ur}, F^{ur}]$: from our previous analysis we know that the entrant finds it optimal to enter with its own infrastructure ($F < F^{ur}$), although from a social perspective it would be preferable to have only the incumbent investing in advanced services ($F > \tilde{F}^{ur}$). We name this scenario as "inefficient entry". Alternatively, when $(\mu, \beta) \in M$ and $F \in (F^{ur}, \tilde{F}^{ur})$, entry would be desirable but the entrant actually does not find it optimal to enter (lack of entry).

In order to interpret the result given i Proposition 1, let us start with the lack of entry scenario. This form of inefficiency can possibly emerge when $(\mu, \beta) \in M$; as displayed in Figure 2, the set M is characterized by large β and large μ. As far as the two threshold levels F^{ur} and $\tilde{F}^{ur}$ is concerned, they vary with β and μ and, in particular, it is possible to show that when β and μ are large they take extremely large values. Large β and μ indicate that firms' investments generate great value and therefore that it is socially desirable to have both firms investing in value added services/quality of the network; nonetheless, entry may not occur due to the large cost of entry: when $(\mu, \beta) \in M$ and $F \in (F^{ur}, \tilde{F}^{ur})$, where, as noted, the two thresholds are very large, the entrant does not enter despite entry would enhance social welfare. On the contrary, inefficient entry may occur when $(\mu, \beta) \notin M$, that is when firms' investments are generally less desirable; in this case, if F is not too large, formally if $F \in (\tilde{F}^{ur}, F^{ur}]$, where the thresholds are of lower magnitude then in the previous case, the entrant does enter although entry is not socially desirable.

On the top of these arguments, there is another aspect that plays a role and that helps interpreting Proposition 1; as discussed in Lemma 1, when μ is sufficiently close to β, firms investments have a public good nature and this yields to a standard problem of under-provision. In this case, competition is not desirable since it depresses investments in value added services; looking at Figure 2, under-provision is particularly severe in the region close to the 45^0 degree line: when μ and β take similar values, entry may not be desirable. If entry does occur, when $F > \tilde{F}^{ur}$, this is not socially efficient.

It is interesting to note that compared to Bourreau and Dogan (2006) our setting provides a more comprehensive picture of the possible forms of inefficiencies that may arise in the presence of a make or buy decision by an entrant operator. In particular, Bourreau and Dogan (2006) use an inter-temporal framework to represent the entrant's choice between building an alternative network or buying access to the incumbent's infrastructure; they model a framework without investments in enhanced services and where the incumbent sets a time-dependent access path for its local loop before the entrant takes its entry decision. In this framework, these authors find that an unregulated incumbent may set an access charge which is too low from a social perspective, hence discouraging (i.e. delaying) the entrant from rolling out its alternative infrastructure. This result is reminiscent of our lack of entry type of inefficiency; we show that this may be only a part of the story: in a setting where both firms may invest in enhanced services and that accounts for different social values of these investments, we have shown that also the inefficient entry form of inefficiency may occur.

2.2 Regulated access

Let us now consider the model when the terms of access are decided by a welfare maximising regulator. As we have described above, we consider two scenarios: *i*) the regulator sets the access charge a after I and E have taken their investment decisions (regulation without commitment) and *ii*) a is decided before the two firms undertake their investments (regulation with commitment).

Note that independently on the type of access regulation, when the entrant opts for facilities based entry, the terms of access are irrelevant; the subgame $b = 1$ is the same as above and in order to solve for the Nash equilibrium of the game we only need to determine the payoffs when access regulation comes into place, that is when entry occurs without E building its own infrastructure.

In what follows we proceed under the assumption $\mu = \beta$, whereby the spillover effect is identical to the own demand effect; we name this scenario as the "complete spillover" case. This assumption allows to simplify the model at the cost of a little loss of generality. In Appendix 2 we extend the discussion of this section to the case with partial spillover, $\mu < \beta$; in order to reassure the reader on the general validity of our results, we highlight the main differences between the complete and the partial spillover scenarios.

2.2.1 Regulation without commitment

We are in the case $b = 0$; in this scenario only the incumbent has the option to invest in enhanced services. Given the access charge, a, competition at the retail level occurs exactly as described in expressions (8). The difference with respect to the previous case is that the access charge is now determined by the regulator that, having observed the incumbent investment decision, sets a to maximize welfare.

The welfare function for the case $b = 0$ is given in expression (11); substituting the output levels (8) and considering that we are now considering the case with $\mu = \beta$, it is immediate to derive the social welfare in terms of the level of the incumbent's investments x_I and of the access charge a:

$$W^{rnc}|_{b=0} = \frac{4(A + \beta x_I)^2}{9} - \frac{a(A + \beta x_I + \frac{a}{2})}{9} - \frac{x_I^2}{2},$$

where the superscript ^{rnc} indicates that we are in the case with regulation and no commitment. The regulator observes x_I and decides a; it is possible to verify that for any $x_I \geq 0$, the above function is decreasing in a, thus implying that the regulator maximizes welfare by setting the access charge at the lowest possible level, namely at the level of the incumbent cost of providing access: $a^{rnc} = 0$. This is natural: by setting the access charge at the cost of providing access the regulator puts the entrant and the incumbent on equal footing, hence promoting the most efficient level of downstream competition.[14]

[14]Clearly, marginal cost pricing is socially optimal provided that I does not incur in a fixed cost of running the network infrastructure; in our model, the fixed cost of infrastructure maintenance are normalized to zero.

Going backwards, the incumbent sets its optimal level of enhanced services; using the fact that the access charge is set at zero by the regulator, the maximisation of (1) with respect to x_I yields the following level of investment:[15]

$$x_I^{*rnc}|_{b=0} = \frac{2A\beta}{9 - 2\beta^2}.$$

Firms' profits and social welfare in this case are therefore:

$$\Pi_I^{*rnc}|_{b=0} = \frac{A^2}{9 - 2\beta^2}, \quad \Pi_E^{*rnc}|_{b=0} = \frac{9A^2}{(9 - 2\beta^2)^2}, \quad \text{and} \quad W^{*rnc}|_{b=0} = \frac{2A^2(18 - \beta^2)}{(9 - 2\beta^2)^2}. \tag{13}$$

Note that, when the access charge is regulated to maximize welfare, service based entry always guarantees positive profits to E. Whether E chooses $b = 1$ or $b = 0$ depends on the comparison between the profits it gets with and without deploying its infrastructure, $\Pi_E^*|_{b=1}$ and $\Pi_E^{*rnc}|_{b=0}$ respectively. In order to proceed, it is useful to define the threshold level of the entrant's fixed cost of infrastructure F^{rnc} as the level such that these two levels of profits are the same; formally, we define F^{rnc} as the entry fixed cost such that $\Pi_E^{*rnc}|_{b=0} = \Pi_E^*|_{b=1}$:

$$F^{rnc} = \frac{2A^2\beta^2(81 - 4\beta^4 - 18\beta^2)}{(9 - 4\beta^2)^2(9 - 2\beta^2)^2}.$$

The following result holds:

Proposition 2. *When the access charge is regulated after operators' investments take place, entry always occurs. When $F \leq F^{rnc}$, the entrant enters with its own infrastructure.*

As expected, regulation acts pro-competitively: independently on the parameters' values, when the access is regulated, entry always occurs at the equilibrium.[16] When the fixed cost of rolling out the alternative network is not too large, the entrant invests and enters the market supplying valued added services.

Basic algebra is enough to show that $F^{rnc} < F^{ur}$;[17] this leads to the observation that when the terms of access are regulated, facility based entry is less likely to occur than without regulation. This is a well known distortion of access regulation: by making the conditions for service based entry more favorable, regulation discourages competitors investments: they prefer to "buy" cheap access rather than to "make" their infrastructure.

[15] The second order condition is satisfied.

[16] It deserves to me highlighted that when $\mu < \beta$, E may decide to stay out even if the regulator sets the access charge at the cost of providing access; this occurs only when μ is vary small compared to β and it represents the main difference with respect the case with $\mu = \beta$. Formal details are in Appendix 2.

[17] From expression (9) is immediate to obtain F^{ur} whit complete spillover; formally, when $\mu = \beta$, $F^{ur} = A^2(9 - 2\beta^2)/(9 - 4\beta^2)^2$.

This distortion suggests that access regulation may turn out to be inefficient; let us investigate this point a bit further by looking at the possibile inefficiencies induced by the regulator. More specifically, access regulation may generate two forms of “failures”:

1. regulation may discourage facilities based entry when this form of entry is socially desirable;

2. due to the stronger competitive pressure that it induces at the retail level, regulation may discourage firm I from investing in enhanced services that are valuable to the society.

Type 1 inefficiency is particularly relevant for intermediate values of F: according to Proposition 2, when the access is regulated, E enters with its own facilities only if $F \leq F^{rnc}$, while service based entry occurs otherwise. Alternatively, absent regulation, E would eventually enter with its own infrastructure. When the cost of building up the network is not too high, it may happen that facilities based entry would be socially preferable to service based entry but the former does not emerge at the regulated equilibrium, thus explaining the inefficiency.

The second type of inefficiency shows up when the cost of the infrastructure is sufficiently large: when $F > F^{ur}$, E stays out of the market when access is not regulated, while it enters without infrastructure when access regulation is in place. In this latter case, the presence of a competitor, whose entry cannot be discouraged by the incumbent, may induce I to reduce the amount of investments in enhanced services.[18] When β is sufficiently large, these investments are so valuable to consumers that social welfare would be higher when only the incumbent firm is active in the market rather than when also E operates via regulated access to the incumbent network.

In the following proposition we present analytically these two forms of regulatory failures. Before stating our next result it is useful to define another threshold level of the fixed cost of networked entry, that we indicate with $\tilde{F}^{rnc}$, defined as the level of F that equates the level of welfare under regulation, $W^{*rnc}|_{b=0}$, to the level of welfare with facilities based entry, $W^{*}|_{b=1}$:

$$\tilde{F}^{rnc} = \frac{2A^2\beta^2(567 - 216\beta^2 + 8\beta^4)}{(3-2\beta)^2(3+2\beta)^2(9-2\beta^2)^2}.$$

[18]Formally, when $F > F^{ur}$, the amount of investments in advanced services with and without regulation are, respectively, $x_I^{*rnc}|_{b=0} = \frac{2A\beta}{9-2\beta^2}$ and $x_I^{*ur}|_{b=0} = \frac{A\beta}{2-\beta^2}$; simple algebra shows that $x_I^{*ur}|_{b=0} > x_I^{*rnc}|_{b=0}$ for any β.

Proposition 3. *Suppose that* $\mu = \beta$; *when* $F^{rnc} < F < min\{\tilde{F}^{rnc}, F^{ur}\}$, *access regulation always reduces welfare (type 1 regulatory failure). When* $F > F^{ur}$ *social welfare is higher without access regulation when* $\beta > \sqrt{23 - \sqrt{241}}/4$ (≈ 0.68) *(type 2 regulatory failure).*

Proof. See Appendix 1. □

As suggested by Proposition 3, the magnitude of the failures strictly depends on customers' evaluation for enhanced services, β; in particular, when customers attach a sufficiently large value to advanced services, access regulation turns out to fail independently on the level of F (either failure of type 1, or of type 2, or of both types of failures). The following Corollary formalizes this observation.

Corollary 1. *Independently of the level of* F, *for* $\beta \geq \sqrt{23 - \sqrt{241}}/4(\approx 0.68)$, *regulation never improves social welfare.*

2.2.2 Regulation with commitment

Let us now focus on the case with regulatory commitment. In this scenario, the regulator moves first and she credibly announces the regulated access charge before E takes its entry decision. Clearly, with respect the previous case, nothing changes in the subgame $b = 1$: if E enters with its own infrastructure, the regulatory environment does not play any role and the pay-offs for this subgame are the same as before.

Let us now focus on the subgame $b = 0$. The Cournot stage is exactly as above; given the access charge, the quantities produced by I and E at the retail level are those obtained imposing in expressions (8).[19]

Going backwards, the incumbent observes a and decides x_I; plugging the Cournot outcomes into I's profit function and solving the first order condition with respect to x_I, we get:

$$x_I^{rc}|_{b=0} = \frac{\beta(2A + 5a)}{9 - 2\beta^2}.$$

where the superscript ^{rc} indicates that we are in a situation with access regulation and regulatory commitment. It is interesting to note that now a becomes an instrument in the regulators' hands that can be used to influence the amount of investments in next generation services; more precisely, $x_I^{rc}|_{b=0}$ increases with a, indicating that a higher access charge stimulates I's investments in enhanced services: a larger a makes the service based rival less

[19] With complete spillover, $\mu = \beta$, expressions (8) reduce to $q_I|_{b=0} = (A + \beta x_I + a)/3$ and $q_E|_{b=0} = (A + \beta x_I - 2a)/3$.

competitive, hence allowing the incumbent to increase its investments. Using $x_I^{rc}|_{b=0}$, the output produced by the entrant given a becomes:

$$q_E^*|_{b=0} = 3\frac{A - a(2-\beta^2)}{9-2\beta^2},$$

which, clearly, decreases with a. It is useful to note that for sufficiently large values of a, this output is driven down to zero and the incumbent forecloses the market; more specifically, we denote with $a_{forec}^{rc} = A/(2-\beta^2)$ the level of the access charge such that for $a \geq a_{forec}^{rc}$, the rival does not find it optimal to enter.

By substituting $q_I^*|_{b=0}$, $q_E^*|_{b=0}$ and $x_I^{rc}|_{b=0}$ obtained in this case, back into the social welfare function, it is possible to derive the level of welfare as a function of a, when $\mu = \beta$:

$$W^{rc}(a)|_{b=0} = \frac{A\,(2\,A\,(18-\beta^2) - (9-32\,\beta^2)\,a) - \frac{1}{2}\,(31\beta^2 - 24\,\beta^4 + 9)\,a^2}{(9-2\,\beta^2)^2}. \tag{14}$$

The regulator, sets the non negative level of a that maximizes welfare; formally, the committed regulator faces the following problem:

$$\max_a \quad W^{rc}(a)|_{b=0}$$
$$s.t. \qquad a \geq 0.$$

The function (14) is concave in a; simple maximization reveals that the optimal level of the access charge is:[20]

$$a^{*rc} = \begin{cases} 0 & \text{if} \quad \beta < \frac{3}{8}\sqrt{2} \\ \frac{A(9-32\beta^2)}{24\beta^4-31\beta^2-9} & \text{if} \quad \frac{3}{8}\sqrt{2} \leq \beta < \frac{\sqrt{3}}{2} \\ \frac{A}{2-\beta^2} & \text{otherwise.} \end{cases}$$

This expression deserves some discussion. When the regulator is able to set a before firms take their investment decisions, the regulatory strategy is in fact more articulated than in the scenario without commitment. More precisely, for sufficiently large values β ($\beta \geq \sqrt{3}/2 \approx 0.86$), the regulator finds it optimal to set the access charge at a_{forec}^{rc}, i.e. level that makes entry via access to I's network no longer profitable. For smaller values of β, the regulated access charge decreases and the regulator makes service based entry profitable,

[20] The unconstrained optimum of $W(a)$ is $\hat{a} = \frac{A(9-32\beta^2)}{24\beta^4-31\beta^2-9}$, which is positive for $\beta > 3\sqrt{2}/8$ and negative otherwise. In this latter case, the constraint is binding and the optimal access charge is $a = 0$. When $\beta \geq \sqrt{3}/2$, $\hat{a} \geq a_{forec}^{rc}$ and $a^{*rc} = A/(2-\beta^2)$. The second order condition for welfare maximization is satisfied.

while for β that takes even smaller values ($\beta < 3\sqrt{2}/8 \approx 0.53$), a is set at the cost of providing access as in the no commitment case.

It is interesting to note that while without commitment optimal regulation always implies marginal cost access pricing, with commitment this occurs only in a restricted set of parameters values, namely when customers' evaluation for value added is sufficiently small. The reason for this regulatory policy relies on the fact that, while without commitment the regulator takes firms' investment decisions as given and the best she can do is to lower a as much as possible to improve market's efficiency in case of service based entry, with commitment the regulator is able, at least to a certain extent, to influence firms' investments. When β is sufficiently large, firms' investments are particulary valuable to the society and entry of an infrastructured operator is socially desirable; in this case, the regulator stimulates facilities based entry by credibly announcing to set the access charge above the marginal cost of providing access. On the contrary, when β is small, facilities based entry has little impact on social welfare and the regulator prefers to entice service based entry by setting a=0. From this discussion emerges how a committed regulator uses a to stimulate the deployment of new infrastructures: by setting a at a sufficiently high level, the regulator may induce E to build its alternative network, a result which is broadly consistent with the ladder of investment theory.[21]

In order to characterize the equilibrium of the entry game, we need to define firms' profits and social welfare when the entrant does not invest in its own infrastructure; using all the above arguments, it is possible to compute the relevant levels of private and social surpluses:

$$\Pi_I^{*rc}|_{b=0} = \begin{cases} \frac{A^2}{9-2\beta^2} & \text{if } \ \beta < \frac{3}{8}\sqrt{2} \\ \frac{A^2(783\beta^2+176\beta^4-576\beta^6-162)^2}{2(31\beta^2-24\beta^4+9)^2} & \text{if } \ \frac{3}{8}\sqrt{2} \leq \beta < \frac{\sqrt{3}}{2} \\ \frac{(18-9\beta^2)A^2}{2(6-3\beta^2)^2} & \text{otherwise,} \end{cases} \tag{15}$$

$$\Pi_E^{*rc}|_{b=0} = \begin{cases} \frac{9A^2}{(9-2\beta^2)^2} & \text{if } \ \beta < \frac{3}{8}\sqrt{2} \\ \frac{(9-12\beta^2)^2A^2}{(31\beta^2-24\beta^4+9)^2} & \text{if } \ \frac{3}{8}\sqrt{2} \leq \beta < \frac{\sqrt{3}}{2} \\ 0 & \text{otherwise,} \end{cases} \tag{16}$$

$$W^{*rc}|_{b=0} = \begin{cases} \frac{2A^2(18-\beta^2)}{(9-2\beta^2)^2} & \text{if } \beta < \frac{3}{8}\sqrt{2} \\ \frac{3A^2(3+8\beta^2)}{2(9+31\beta^2-24\beta^4)} & \text{if } \frac{3}{8}\sqrt{2} \leq \beta < \frac{\sqrt{3}}{2} \\ \frac{A^2(3-\beta^2)}{2(2-\beta^2)^2} & \text{otherwise.} \end{cases} \tag{17}$$

[21] Although in a different scenario, our conclusion is also reminiscent of a similar result obtained in Avenali et al. (2010).

As in the previous cases, the equilibrium of the game emerges from the comparison between the level of profits that E is able to obtain with and without the investment in infrastructures. The result is presented in the following proposition:

Proposition 4. *Suppose $\mu = \beta$; when the regulator is credibly committed to regulate the access charge at a^{*rc}, the equilibrium of the entry game is the following: if $\beta \geq \sqrt{3}/2$ only facilities based entry occurs, provided that $F \leq F^{ur}$; when $\beta < \sqrt{3}/2$ entry, either service or facilities based, always occurs. In this last case, the entrant enters with its own infrastructure if $F \leq F^{rc}$ while service based entry occurs otherwise, where:*

$$F^{rc} = \begin{cases} F^{rnc} & \text{if } \quad \beta \leq \frac{3}{8}\sqrt{2} \\ \frac{A^2\left(5856\,\beta^8 - 626\,\beta^6 - 24867\,\beta^4 + 28188\,\beta^2 - 5832 - 1152\,\beta^{10}\right)}{(24\,\beta^4 - 31\,\beta^2 - 9)^2(4\,\beta^2 - 9)^2} & \text{otherwise.} \end{cases} \tag{18}$$

Proof. The proposition follows from a comparison between the level of profit that E gets by deploying its infrastructure, $\Pi^*_E|_{b=1}$ given in (7), and the amount it gets by seeking access to the incumbent's network, $\Pi^{*rc}_E|_{b=0}$ given in (16). □

This proposition highlights the properties of the entry game with committed regulator. As explained above, for sufficiently large values of β, the regulator optimally commits herself to set the access charge at a^{rc}_{forec} to prevent service based entry and to stimulate E's investment. This means that when $\beta \geq \sqrt{3}/2$, the entrant faces a situation identical to the unregulated case in which service based entry is not an option and facilities based entry occurs only if the fixed cost of building an infrastructure is non too large, namely $F \leq F^{ur}$. This explains the first part of Proposition 4.

When $\beta < \sqrt{3}/2$, customers give smaller value to enhanced services and there is less need to stimulate investments; in such a situation, the regulator sets the access in a way to guarantee that, with certainty, a form of competition will emerge at the equilibrium; the type of entry actually chosen by E, either service or facilities based, will depend on the magnitude of F: for values equal or smaller than F^{rc}, E will enter with its own infrastructure, while service based entry will occur otherwise.

Figure 3 provides a graphical representation of the entrant choice at the equilibrium when the regulator moves first.[22] For β and F below the solid line, E enters facility based; for values above it, service based entry occurs for $\beta < \sqrt{3}/2$ while E stays out altogether for larger β.

[22]In the diagram, the various thresholds are drawn with respect to β; A is simply a scale parameter and it does not affect the shape of the functions.

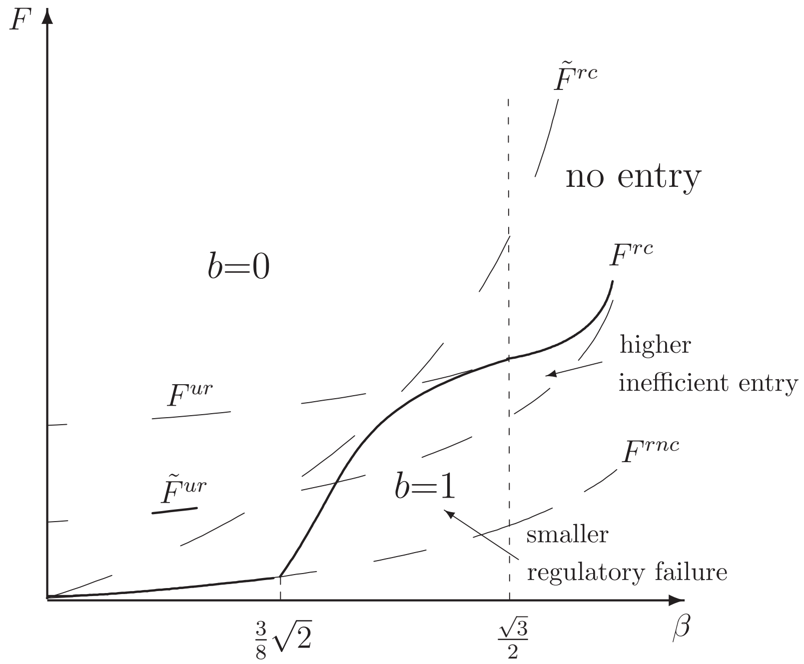

Figure 3: entry choices with access regulation and commitment

Being the regulator able to influence firms' investments decisions, one may wonder whether with commitment access regulation entails smaller regulatory failures. Figure 3 may help to answer to this point and in order to compare the inefficiencies in the two regimes we have drawn also the other relevant threshold levels of the fixed cost of networked entry, F^{rnc}, F^{ur}, $\tilde{F}^{ur}$ and $\tilde{F}^{rnc}$.

If, on the one side, regulatory commitment tends to reduce regulatory failures, on the other it has an ambiguous effect on stimulating inefficient entry. With respect to regulatory failures, we know from the previous section that access regulation may deter socially desirable facilities based entry (type 1 regulatory failures).[23] When the regulator is credibly committed to charge a^{*rc}, this failures are less likely to occur; this can be easily verified by looking at the threshold level F^{rc} (the solid line in Figure 3). For $\beta > 3\sqrt{2}/8$, F^{rc} is larger than the un-committed counterpart F^{rnc}: facilities based entry occurs less frequently and despite regulatory failure of type 1 may still occur, it may happen in a smaller set of parameters' values. In other words, when the regulator is committed to adopt the regulatory policy a^{*rc}, this failure is less severe. As documented in Figure 3, this occurs when $\beta \in (3\sqrt{2}/8, \sqrt{3}/2)$.

[23]It is useful to remember that with complete spillover only inefficient entry may occur at the unregulated equilibrium. See Figure 2.

On the other side, we have shown that when $\beta \geq \sqrt{3}/2$, a^{*rc} is set to make service based entry not profitable. As discussed above, in this case E faces a scenario that mimics perfectly the unregulated one and the equilibrium of the game also resembles the inefficiencies of this latter case (see Proposition 1); as shown in Figure 3, when $\beta > \sqrt{3}/2$, any time $F < F^{rc}$ (that coincides with F^{ur} for these values of β) inefficient entry may occur.

Corollary 2. *Suppose $\mu = \beta$. Compared with the case with uncommitted regulation, the equilibrium of the entry game with regulatory commitment shows less regulatory failure when $\beta \in (3\sqrt{2}/8, \sqrt{3}/2]$ and larger inefficient entry when $\beta > \sqrt{3}/2$.*

3 The model with bilateral access

Consider facilities based entry; so far, we have implicitly assumed that the two firms would have reciprocally interconnected their networks for free, namely that I and E were able to exchange freely traffic and data. This interconnection scheme where the reciprocal termination charge is zero, is usually referred to as Bill and Keep (B&K). Since in our model we have also implicitly assumed zero marginal cost of interconnection, this scenario is consistent with a cost based interconnection regime.

Bill & Keep is one possible form of interconnection; indeed, there is currently a lively debate about which would be the best interconnection regime in the emerging world of the next generation networks (Marcus, 2007). One of the alternatives that has attracted the attention of practitioners and policy makers is negotiated bilateral access, an interconnection regime that has been widely applied to traditional telephony; with bilateral access, the two networked operators need to collaborate on the determination of a symmetric interconnection charge. It is interesting to evaluate how the predictions of the model would change when I and E need to preliminary agree upon the terms of interconnection. The assumption of reciprocal interconnection is natural in our context where, in case of b=1, the two infrastructured operators are identical; therefore, we assume that the amount that I pays to E in order to access its network is the same that E pays to I for access in the opposite direction. We will assume that the interconnection charge $t \geq 0$, *i*) is linear and payments occur in proportion to the amount of traffic exchanged and *ii*) is determined following a Nash bargaining process characterized by the two firms having the same bargaining power.[24]

[24]It must be said that with fixed or two-part interconnections charges, things may change radically. These extensions of the basic model go beyond the scopes of the present paper; the interested reader may refer to Laffont and Tirole (2000) for a syntheses of the literature on interconnection regimes. See also Vogelsang (2003) for a survey of the major contributions.

According to these assumptions, firm I pays E the amount tq_I for interconnection and receives tq_E from the rival. Formally, when $\mu = \beta$, the profit functions of the two operators in case $b = 1$ become:[25]

$$\Pi_{I,int}|_{b=1} = (A + \beta(x_I + x_E) - q_I - q_E)q_I - tq_I + tq_E - C(x_I), \tag{19}$$

and

$$\Pi_{E,int}|_{b=1} = (A + \beta(x_E + x_I) - q_I - q_E)q_E - tq_E + tq_I - C(x_E) - F, \tag{20}$$

where the subscript ^{int} reminds us that we are currently analyzing the model with bilateral interconnection. We proceed by backward induction and we start from the last stage of the game when the two firms compete "á la Cournot"; I and E set their profit maximizing quantities, that, given t, are $(A+\beta(x_I+x_E)-t)/3$. Substituting these expressions back into I and E profit functions is possible to rewrite them in terms of t:

$$\Pi_{I,int}|_{b=1} = \left(\frac{A + \beta(x_I + x_E) + 2t}{3}\right)\left(\frac{A + \beta(x_I + x_E) - t}{3}\right) - \frac{{x_I}^2}{2},$$

and

$$\Pi_{E,int}|_{b=1} = \left(\frac{A + \beta(x_I + x_E) + 2t}{3}\right)\left(\frac{A + \beta(x_I + x_E) - t}{3}\right) - F - \frac{{x_E}^2}{2}.$$

In the last but one stage, given their investments, I and E negotiate the reciprocal interconnection charge t; negotiations take the form of a Nash-bargaining process in which the contracting parties have the same bargaining power. Formally, the interconnection charge is given by:

$$t = argmax\left[\Pi^{1/2}_{I,int}|_{b=1}\Pi^{1/2}_{E,int}|_{b=1}\right]. \tag{21}$$

For the sake of simplicity, we assume that the disagreement point of this bargaining process is that there is no interconnection agreement, namely the firms cannot compete and their profits go to zero.[26]

Solving expression (21), the negotiated interconnection charge given the amount of investments, is:

$$t^* = \frac{A + \beta(x_I + x_E)}{4}. \tag{22}$$

[25]The results of this section are valid also in the more general case of $\mu \leq \beta$; nonetheless, due to its algebraic complexity, we omit the formal proof. A simulation of the solution of the model with reciprocally interconnected networks with partial spillover can be downloaded at `www.decon.unipd.it/personale/curri/manenti/academic/papers/interc-partial.pdf`.

[26]In a less extreme, but formally equivalent, scenario, one can assume that absent an agreement, both firms need to interconnect indirectly through the internet cloud at the cost of being prevented from the provision of advanced services.

It is interesting to note that t^* increases both with β and with x_I and x_E. Once determined the optimal interconnection charge, one can go back to the previous stage and solve for the investments levels. Using t^*, firms profits can be rewritten as:

$$\Pi_{I,int}|_{b=1} = \frac{(A+\beta(x_I+x_E))^2}{8} - \frac{x_I^2}{2}, \quad \text{and} \quad \Pi_{E,int}|_{b=1} = \frac{(A+\beta(x_I+x_E))^2}{8} - \frac{x_E^2}{2} - F.$$

Profit maximization reveals that the amount of value added investments undertaken by the two firms at the equilibrium in this case is $x^*_{I,int} = x^*_{E,int} = A\beta/(2(2-\beta^2))$.[27] Interestingly, looking at these expressions, it emerges that when firms interconnect negotiating the terms of the reciprocal access, *i*) they are induced to invest more in enhanced services than with B&K/cost based interconnection and *ii*) economy-wide investments are identical to those that would be incurred by an unregulated monopolist, $x^*_{I,int} + x^*_{E,int} = x_I^{*ur}|_{b=0}$. The reason for these results is simple: as it has been widely studied in the literature on networks interconnection, the bilateral access charge represents an instrument that firms use to implicitly collude (Carter and Wright, 1999; Laffont and Tirole, 2000): firms anticipate at the investment stage that they will collude at the retail level through the negotiation on t and are therefore induced to invest more in enhanced services in the first place. Thanks to the interconnection charge, firms are able to replicate the monopolistic scenario.

Using $x^*_{I,int}$ and $x^*_{E,int}$, it is immediate to derive the level of profits and the welfare with interconnected networks:

$$\Pi^*_{I,int}|_{b=1} = \frac{A^2\left(4-\beta^2\right)}{8\left(2-\beta^2\right)^2}, \quad \text{and} \quad \Pi^*_{E,int}|_{b=1} = \Pi^*_{I,int}|_{b=1} - F, \tag{23}$$

and

$$W^*_{int}|_{b=1} = \frac{A^2\left(6-\beta^2\right)}{4\left(2-\beta^2\right)^2} - F. \tag{24}$$

Clearly, bilateral access occurs only in the sub-game characterized by E joining the market with its own infrastructure, while the other scenarios remain identical to those analyzed in the previous sections (with or without access regulation).

Let us focus on the unregulated scenario. As in Section 2.1, when the access charge is not regulated, I will set it in order to prevent service based entry. As before, E enters with its own infrastructure only if $\Pi^*_{E,int}|_{b=1} \geq 0$; looking at expressions (23), entry occurs when $F \leq F^{ur}_{int}$, where $F^{ur}_{int} = A^2\left(4-\beta^2\right)/(8\left(2-\beta^2\right)^2)$. A simple comparison between the two threshold levels with B&K and with bilateral interconnection, reveals that $F^{ur}_{int} > F^{ur}$; this condition implies that when firms negotiate the terms of interconnection, there is more room

[27] Second order conditions are satisfied.

for facilities based entry: a firm with a cost of entry such that $F^{ur} < F \leq F^{ur}_{int}$, would have not found profitable to enter in the presence of B&K interconnection scheme while it enters the market if bilateral access is negotiated.

Proposition 5. *When firms interconnect through a negotiated reciprocal access charge, more facilities based entry occurs.*

Obviously, this will translate into more inefficient entry and, therefore also in lower social surplus; visual inspection of the profits enjoyed by the two firms and of the social welfare with and without bilateral interconnection, respectively given in expressions (23)-(7) and (24)-(10) reveals that when I and E interconnect at the bilateral access charge t^* they enjoy higher profits but the social welfare is lower. Again, this is another effect of t as a collusive instrument; collusion has two effects: on the one side, firms invest more in enhanced services and, on the other side, they collude to limit retail competition. While the first effect goes to the benefit of consumers, the second one goes clearly in the opposite direction. At the equilibrium, the former dominates.

Finally, let us move on to the scenario with regulated access. For ease of exposition, we focus only on the case without commitment. In Section 3.1 we have shown under which circumstances regulation goes to the detriment of social welfare; indeed, Corollary 1 shows that for sufficiently large values of β, regulation always hurts social surplus. In the Proof of the proposition we have also shown that regulatory failures may emerge also when β is small (see Figure 4 in the Proof of Proposition 3).

When the two firms agree upon the interconnection charge t^* in case of facilities based entry, it is possible to show the following result:

Proposition 6. *Compared to the unregulated equilibrium,* $\beta < \sqrt{23 - \sqrt{241}}/4$ *(*≈ 0.68*) is a sufficient condition for access regulation not to reduce welfare.*

Proof. See Appendix 1. □

This Proposition is interesting and shows that when firms negotiate to interconnect at t^* in case of facilities based entry, access regulation may actually improve social welfare; at least for $\beta < 0.68$, there are no regulatory failures. The reason for this result is quite intuitive: as we have seen, with bilateral access there is the tendency towards more infrastructured entry and in case of entry, firms collude via t. Since access regulation makes service based entry more likely to occur, it reduces facilities based entry and the occurrence of collusion. Regulatory failures may still emerge when β is large; as already noticed, the welfare loss due to bilateral interconnection becomes smaller and the social desirability of deterring facilities based entry is therefore lower.

4 Concluding remarks

In this paper we propose a theoretical model where an incumbent and an entrant firm compete in the market for advanced communications services. We model a scenario where an entrant firm has to decide whether to enter the market with its own infrastructure or by buying access from the incumbent; in the latter case, the terms of access may be set by a welfare maximizing regulator. Infrastructured operators (namely, the incumbent and the facility based entrant) have also the opportunity to invest in order to provide advanced communications services.

The aim of the paper is to study the impact of access regulation on the type of entry (service based vs facility based) and on the amount of investments in advanced communications services.

Consistently with existing economic literature, we find that when the access charge is not regulated, the incumbent finds it optimal to foreclose service based entry by fixing a sufficiently high access price. Only facility based entry may occur at the unregulated equilibrium; we show that entry may be inefficient in the sense that the entrant may be induced to enter after having rolled out its infrastructure even though this is not socially optimal. However, we also show that for a possibly large subset of the parameters' space, facility based entry does not occur at the equilibrium even though it would be socially desirable.

When the access charge is regulated ex-post (after firms investments) regulatory failures may emerge; access regulation promotes service based entry also when facility based entry would be socially desirable (and it would actually emerge at the equilibrium without regulation). When access charge is regulated ex-ante (before firms invest in advanced services), regulatory failures can be reduced but not eliminated.

Finally we extend the model to encompass the case of negotiated interconnection between infrastructured operators. We show that inefficient infrastructured entry tends to be more severe in this case; on the contrary access regulation appears to be less detrimental to social welfare than in the case of Bill & Keep interconnection regime.

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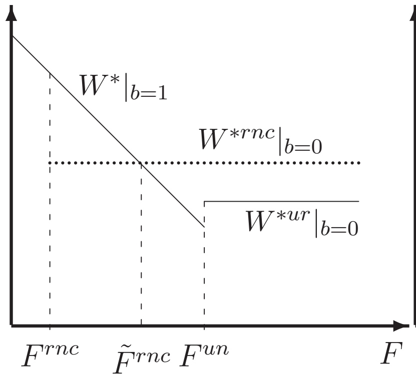

Figure 4: $\beta < \underline{\beta}$

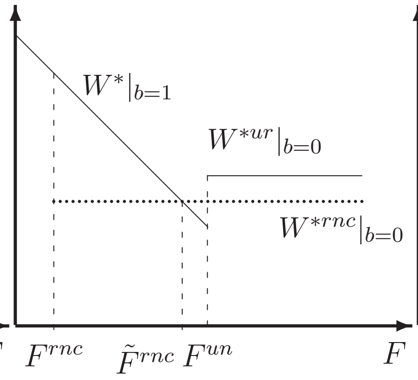

Figure 5: $\underline{\beta} < \beta < \overline{\beta}$

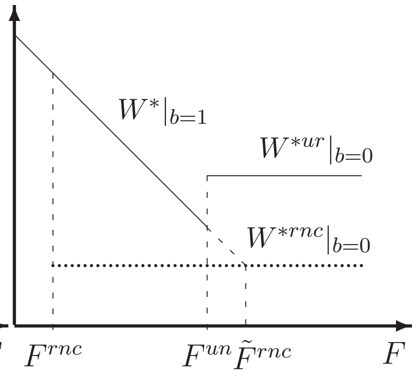

Figure 6: $\beta > \overline{\beta}$

Appendix 1

Proof of Proposition 3. Regulatory failures emerge from a comparison between the welfare level with and without regulation. Without regulation, the social welfare enjoyed at the equilibrium is $W^*|_{b=1}$ for $F \leq F^{ur}$ and $W^{*ur}|_{b=0}$ otherwise (see expressions (10) and (12)), while with access regulation the social welfare is $W^*|_{b=1}$ for $F \leq F^{rnc}$ and $W^{*rnc}|_{b=0}$ (see expression (13)) for larger values of F, with $F^{rnc} < F^{ur}$.

Clearly, regulation is irrelevant for $F \leq F^{rnc}$ since in this case the equilibrium level of welfare is the same in both cases; for $F > F^{rnc}$ it is useful to distinguish three possible scenarios: *i)* $\beta < \underline{\beta}$ (low β), *ii)* $\underline{\beta} \leq \beta < \overline{\beta}$ (intermediate values of β) and *iii)* $\beta \geq \overline{\beta}$ (high values of β), where:

$$\underline{\beta} = \frac{\sqrt{23 - \sqrt{241}}}{4} \approx 0.68 \quad \overline{\beta} = \frac{\sqrt{32061660 + 1603083 \sqrt[3]{2924} + 120615 \sqrt[3]{2924}}}{731 \sqrt[3]{2924} + 55 \sqrt[3]{2924^2} + 14620} \approx 0.73.$$

Figures (4)-(6) provide a graphical representation of these scenarios. In order to prove the Proposition, it is useful to note that:[28]

1. $W^*|_{b=1}$ decreases with F and its value at $F = F^{rnc}$ is larger than $W^{*rnc}|_{b=0}$ for any β; furthermore, $W^*|_{b=1} > W^{*rnc}|_{b=0}$ for $F < \tilde{F}^{rnc}$, where: *i)* $\tilde{F}^{rnc} > F^{rnc}$ for any β and *ii)* $\tilde{F}^{rnc} > F^{ur}$ for $\beta > \overline{\beta}$.

2. $W^{*ur}|_{b=0} > W^{*rnc}|_{b=0}$ for $\beta > \underline{\beta}$.

From all these observations, figures (4)-(6) immediately follow and so the proposition. □

[28] To show these statements some algebra is required. We leave the formal proof available upon request from the authors.

Proof of Proposition 6 . We prove this proposition following the same lines of reasoning of the Proof of Proposition 3. Without regulation, the social welfare enjoyed at the equilibrium is $W^*_{int}|_{b=1}$, defined in expression (24), for $F \leq F^{ur}_{int}$ and $W^{*ur}|_{b=0}$, defined in expression (12), otherwise; with access regulation the social welfare is $W^*_{int}|_{b=1}$ for $F \leq F^{rnc}_{int}$ and $W^{*rnc}|_{b=0}$, defined in (13), for larger values of F, where $F^{rnc}_{int} = \frac{A^2(36-4\beta^6-20\beta^4+63\beta^2)}{8(2-\beta^2)^2(9-2\beta^2)^2}$ is the threshold level of the entry fixed cost such that $\Pi^{*rnc}_E|_{b=0} = \Pi^*_{E,int}|_{b=1}$; note that $F^{rnc}_{int} < F^{ur}_{int}$. Therefore, the level of welfare enjoyed by the society when the access is regulated is given by:

$$\begin{cases} \frac{A^2(6-\beta^2)}{4(2-\beta^2)^2} - F & F \leq F^{ur}_{int} \\ \frac{A^2(3-\beta^2)}{2(2-\beta^2)^2} & otherwise, \end{cases}$$

while the amount of welfare without regulation is given by:

$$\begin{cases} \frac{A^2(6-\beta^2)}{4(2-\beta^2)^2} - F & F \leq F^{rnc}_{int} \\ \frac{2A^2(18-\beta^2)}{(9-2\,\beta^2)^2} & otherwise. \end{cases}$$

Clearly, for $F \leq F^{rnc}_{int}$, E chooses b=1 both with and without regulation, which is, in fact, ineffective. For larger values of F, $W^*_{int}|_{b=1}$ decreases with F while $W^{rnc*}|_{b=0}$ is independent from F; standard math is enough to show that for $\beta < \sqrt{23-\sqrt{241}}/4$: *i)* $W^{rnc*}|_{b=0} > W^*_{int}|_{b=1}$ when $F < F^{ur}_{int}$, and *ii)* $W^{rnc*}|_{b=0} > W^{*ur}_{int}|_{b=0}$ when $F \geq F^{ur}_{int}$. This is enough to prove the proposition. □

Appendix 2: Access regulation with partial spillover.

In the paper, the analysis of the entry game with access regulation is made under the simplifying assumption of complete spillover. In this appendix we show how our results may change introducing partial spillover. As it will become clear below, the equilibrium of the game may differ between the two scenarios, although these differences are qualitatively relevant only when β and μ differ significantly. As expected, when μ and β are not too much diverse, the two scenarios deliver consistent results.

Let us start with the main difference between the complete and the partial spillover case and that holds both with and without commitment: for extremely incomplete spillover (μ very small compared to β), access regulation does not necessarily entice entry; more precisely, the entrant may prefer to stay out rather than demanding access to the incumbent even when the regulator sets the access charge at the marginal cost. Formally, it is possible to prove the following:

Proposition A1. *Suppose the access charge is regulated after operators' investments take place; in this case when $\beta > \sqrt{3}/2$ and $\mu < (3\beta - \sqrt{\beta^2+6})/2$ only facilities based entry may occur for $F \leq F^{*ur}_{ps}$.*

Proof. The output levels produced by the two firms in case of service based entry are given in expressions (8); therefore, given the incumbent's amount of investments in enhanced services x_I, when the access charge is set at marginal cost, the incumbent and the entrant produce $q_E|_{b=0} = (A + (\beta - 2\mu)x_I)/3$ and $q_I|_{b=0} = (A + (2\beta - \mu)x_I)/3$, respectively.
Using these output levels, we can rewrite I's profit in terms of x_I:

$$\Pi_I|_{b=0} = \left(\frac{A + (2\beta - \mu)x_I}{3}\right)^2 - \frac{x_I^2}{2}.$$

Solving for the optimal amount of investments, we get $x_I^* = 2A(2\beta - \mu)/(9 - 8\beta^2 + 8\beta\mu - 2\mu^2)$; plugging this expression back into $q_E|_{b=0}$ found above, it emerges that the level of output that E produces at the equilibrium when the regulator sets the access charge at cost is:

$$q_E^*|_{b=0} = \frac{A\left(3 - 4\beta^2 + 6\beta\mu - 2\mu^2\right)}{9 - 8\beta^2 + 8\beta\mu - 2\mu^2}.$$

It is immediate to verify that this expression is positive only for $\beta < \sqrt{3}/2$ and $\mu > (3\beta - \sqrt{\beta^2 + 6})/2$. □

This Proposition shows that when the direct value generated by firms investments is sufficiently strong and the spillover is sufficiently weak ($\beta > \sqrt{3}/2$ and $\mu < (3\beta - \sqrt{\beta^2 + 6})/2$), access regulation is completely ineffective: the incumbent uses its investment in enhanced services to prevent service based entry[29] and the equilibrium of the entry game in this case perfectly resembles the unregulated scenario with E that enters with its own network only if the fixed cost of rolling out the infrastructure is small enough (formally when $F \leq F^{ur}$). It is easy to verify that a sufficient condition for Proposition A1 to hold is that $\mu < (3 - \sqrt{7})/2$ (≈ 0.18): independently on the value of β, when $\mu < 0.18$, access regulation does not induce service based entry.

Beyond what stated in Proposition A1, the model with partial spillover and access regulation without commitment is not qualitatively different from the case with full spillover.

Consider now the case of committed regulation. Obviously, the optimal access charge is different with respect the one found with complete spillover since it depends also on μ; nonetheless also in this case it can be shown that the characteristics of the equilibrium do not change qualitatively with respect the case $\mu = \beta$.[30]

[29] This result resembles similar arguments obtained in Foros (2004) in a framework without facilities based entry.

[30] The formal treatment is omitted and it is made available to the interested reader on request.

Access Regulation, Entry and Investments in Telecommunications

By Fabio M. Manenti & Antonio Scialà

HIGHLIGHTS

In this paper we propose a theoretical model where an incumbent and an entrant firm compete in the market for advanced communications services. We model a scenario where an entrant firm has to decide whether to enter the market with its own infrastructure or by buying access from the incumbent; in the latter case, the terms of access may be set by a welfare maximizing regulator. Infrastructured operators (namely, the incumbent and the facility based entrant) have also the opportunity to invest in order to provide advanced communications services.

The aim of the paper is to study the impact of access regulation on the type of entry (service based vs facility based) and on the amount of investments in advanced communications services.

We find that:

1. When the access charge is not regulated, the incumbent finds it optimal to foreclose service based entry by fixing a sufficiently high access price. Only facility based entry may occur at the unregulated equilibrium; we show that entry may be inefficient in the sense that the entrant may be induced to enter after having rolled out its infrastructure even though this is not socially optimal. However, we also show that for a possibly large subset of the parameters' space, facility based entry does not occur at the equilibrium even though it would be socially desirable.
2. When the access charge is regulated ex-post (after firms investments) regulatory failures may emerge; access regulation promotes service based entry also when facility based entry would be socially desirable (and it would actually emerge at the equilibrium without regulation).
3. When access charge is regulated ex-ante (before firms invest in advanced services), regulatory failures can be reduced but not eliminated.
4. When infrastructured operators negotiate a reciprocal interconnection charge (this occurs only when the entrant enters facility based), inefficient entry tends to be more severe; on the contrary access regulation appears to be less detrimental to social welfare than in the case of Bill & Keep interconnection regime.