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ACCESS REGULATION, ENTRY AND THE INVESTMENT LADDER IN TELECOMMUNICATIONS

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Access Regulation, Entry and the Investment Ladder 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. Without regulation, we find that the incumbent sets the access charge to prevent resale based entry and this overstimulates rival's investment that may turn out to be socially inefficient. 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 seems 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 the deployment of access networks alternative to that of the incumbents' much more affordable (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 network 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 operators may invest in the provision of next generation services before retail competition takes place. Until

[1]A preliminary empirical analysis of the ladder of investment is in Distaso et al. (2009); the authors show that the policies adopted by National Regulatory Authorities are broadly consistent with this regulatory approach.

[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.

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 and despite this makes the market more competitive, it 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 analyses are made under the implicit assumption of "Bill & Keep" interconnection where, in case of facilities based entry, the incumbent and the entrant operators interconnect their infrastructures at no charge. This is only one of the possible forms of interconnection between next generation networks 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. In a model where only the incumbent is allowed to invest in Next

Generation Network to improve the quality of retail services,[4] they show that, compared to the case without regulatory commitment, regulatory commitment stimulates incumbent's investment. In Brito et al. (2010), the regulator trades-off between reducing the incumbent's market power and giving it more incentives to invest.

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. 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. The main limitation of this paper is in the role of the incumbent, which passively observes the entrant's behavior. More realistically, we allow for a more active role of the incumbent which may invest in enhanced services in response to the entrant decisions; we believe that our framework, that separates the investment in the construction of a new infrastructure from the investment in enhanced services, more closely resembles a real world scenario.

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

[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 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.

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 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 represents an input for the 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. 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

[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 normalised 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.

a natural interpretation when looking at the cost of rolling-out a next generation network. 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). 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 rolls-out its advanced 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. Therefore, in this stylized framework, F can be reinterpreted as the entrant's cost disadvantage with respect the incumbent in rolling out the alternative infrastructure.

It deserves also to be noted that 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 invest in order to offer advanced services, without the need to access the incumbent's network.

The timing of the 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 $C(x_i)$,

[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.

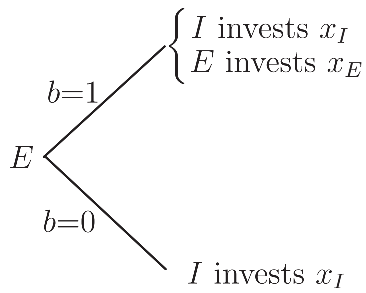

Figure 1: the dynamic structure of the investments

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. 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 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 i's QoS, may stimulate 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:

$$P_I|_{b=0} = A + \beta x_I - q_I - q_E, \qquad P_E|_{b=0} = A + \mu x_I - q_I - q_E, \tag{1}$$

in case of service based entry (b=0); alternatively, in case of facilities based entry (b=1), both firms may invest in value added services and the demand functions are:

$$P_I|_{b=1} = A + \beta x_I + \mu x_E - q_I - q_E, \qquad P_E|_{b=1} = A + \beta x_E + \mu x_I - q_I - q_E, \tag{2}$$

where $\beta \in [0, 1]$ represents the own demand effect of the investment in value added services, and $\mu \in [0, \beta]$ the spillover effect. It is natural to assume that $\mu \leq \beta$, namely that the spillover cannot be larger that 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. Using expressions (1), when E enters without infrastructure, incumbent's and entrant's profits are respectively given by:

$$\Pi_I|_{b=0} = (A + \beta x_I - q_I - q_E - c_o - c_I)q_I + (a - c_o)q_E - C(x_I), \tag{3}$$

and

$$\Pi_E|_{b=0} = (A + \mu x_I - q_I - q_E - a - c_E)q_E, \tag{4}$$

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 (3), 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, using expression (2), I's and E's profits are respectively given by:

$$\Pi_I|_{b=1} = (A + \beta x_I + \mu x_E - q_I - q_E - c_o - c_I)q_I - C(x_I), \tag{5}$$

and

$$\Pi_E|_{b=1} = (A + \beta x_E + \mu x_I - q_I - q_E - c_o - c_E)q_E - C(x_E) - F, \tag{6}$$

where F and $C(x_E)$ represent E's fixed cost of rolling out the alternative infrastructure and the amount of investments 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: $C(x_i) = \frac{x_i^2}{2}$.

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 with commitment and *ii*) access regulation without commitment. In the former case, the regulator intervenes before firms have taken their investments decisions and she finds a way to commit to her regulatory decision afterwards, while in the latter case the regulator, which in this case is assumed to be unable to commit to a long run decision, 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:

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.

In the paper, we will solve for the equilibrium of the game in the three regulatory regimes. We will proceed under the simplifying assumption $\mu = \beta$, whereby the spillover effect is identical to the own demand effect. This allows us to obtain manageable solutions with little loss of generality; in order to reassure the reader on the generality of our results, in the appendix we generalize the model to the case with $\mu < \beta$, and we discuss the main differences with the reference case.

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 infrastructures (b=1), the incumbent and the entrant set, respectively, q_I and q_E in order to maximize their respective profits given in (6). Cournot outcomes are therefore:

$$q_I^*|_{b=1} = q_E^*|_{b=1} = \frac{A + \beta(x_I + x_E)}{3}. \tag{7}$$

Substituting these expressions back into the profit functions and maximising 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:[8]

$$x_I^*|_{b=1} = x_E^*|_{b=1} = \frac{2\beta A}{9-4\beta^2}. \tag{8}$$

Finally, using all these expressions, firms' profits with facilities based entry are as follows:

$$\Pi_I^*|_{b=1} = \frac{A^2(9-2\beta^2)}{(9-4\beta^2)^2}, \quad \text{and} \quad \Pi_E^*|_{b=1} = \Pi_I^*|_{b=1} - F. \tag{9}$$

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 (3) and (4), it is possible to derive the optimal output sold by the two firms as a function of a:

$$q_I^*|_{b=0} = \frac{A+\beta x_I + a}{3}, \quad \text{and} \quad q_E^*|_{b=0} = \frac{A+\beta x_I - 2a}{3}. \tag{10}$$

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 (10):

$$a^{ur} = \frac{A+\beta x_I}{2},$$

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 $x_I^{*ur}|_{b=0} = \frac{A\beta}{2-\beta^2}$. It is interesting to note that the industry-wide amount of investments in enhanced services in case of facilities based entry, $x_I^*|_{b=1} + x_E^*|_{b=1}$, is lower than $x_I^{*ur}|_{b=0}$; the reason is evident: provided that firm j benefits of i's investments in enhanced services due to the spillover effect, they have the typical nature of a public good. The equilibrium shows underinvestment due to firms' opportunistic behavior.

When the incumbent is left free to set the access charge, the entrant cannot enter without the deployment of its own network and the incumbent is able to replicate the level of profits that it would have enjoyed without the threat of entry: $\Pi_I^{*ur}|_{b=0} = \frac{A^2}{2(2-\beta^2)}$.

[8]The second order conditions are satisfied.

From expressions (9), it emerges immediately that E enters and invests in its own infrastructures only if $F \leq F^{ur}$, where

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

This result is well known in the economic literature.[9] The incumbent uses the access charge to deter service based entry; E may, eventually, enter only after having invested in its own network: only facilities based entry may occur and this is possible only when the cost of the investment F is not too large.

Note that F^{ur} increases with β; indeed, the larger β, the more value is generated by the investments in value added services - carried-out by both firms - and the higher the post entry profit for E; hence, as β takes larger values, E enters also when F is larger.[10]

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:

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

Using the equilibrium expressions $x_i^*|_{b=1}$, $q_i^*|_{b=1}$, $\Pi_I^*|_{b=1}$ and $\Pi_E^*|_{b=1}$, 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:

$$W^*|_{b=1} = \frac{4A^2(9-\beta^2)}{(9-4\beta^2)^2} - F. \tag{11}$$

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:

$$W|_{b=0} = \sum_{i=I,E} \frac{(A+\beta x_I - P_i|_{b=0})q_i}{2} + P_I|_{b=0}q_I + aq_E + (P_E|_{b=0} - a)q_E - \frac{x_I^2}{2}.$$

Using the definitions of the demand schedules given in (1), this function can be simplified as follows:

$$W|_{b=0} = \frac{(q_I+q_E)^2}{2} + (A+\beta x_I - q_I - q_E)(q_I+q_E) - \frac{x_I^2}{2}. \tag{12}$$

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

[10] Note $F^{ur} > 0$ for any $\beta \in (0,1]$.

This last 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 the quantities sold by the two firms and 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:

$$W^{*ur}|_{b=0} = \frac{A^2(3-\beta^2)}{2(2-\beta^2)^2}. \tag{13}$$

Without access regulation, we know that at the equilibrium only infrastructured entry may occur if $F \leq F^{ur}$. A comparison between the welfare levels with facilities based entry and without entry given in expressions (11) and (13) reveals an interesting aspect of the equilibrium. Let us define $\tilde{F}^{ur}$ as the level of the entrant's fixed cost such that $W^{*ur}|_{b=0}$=$W^*|_{b=1}$:

$$\tilde{F}^{ur} = \frac{A^2(16\beta^4 + 23\beta^2 - 45 - 8\beta^6)}{2(2-\beta^2)^2(9-4\beta^2)^2}. \tag{14}$$

By definition, whenever $F > \tilde{F}^{ur}$, social welfare is higher under monopoly then with facilities based competition. Simple algebra is enough to check that $\tilde{F}^{ur} < F^{ur}$, $\forall \beta \in [0,1]$; this implies that the equilibrium of the game without regulation may be socially inefficient:

Proposition 1. *Without access regulation, entry may be socially inefficient: when $\tilde{F}^{ur} < F \leq F^{ur}$, entry occurs but the social welfare is higher without entry.*

Figure 2 provides a graphical representation of this result, which is somehow neglected in the existing literature. Facilities based competition has two effects on social welfare: on the one side, competition increases market's efficiency through lower prices, on the other side, as we have seen above, economy-wide investments in enhanced services are lower when E enters the market than otherwise due to public good arguments, and this translates into lower social surplus. Proposition 1 shows that when the cost of entry is large enough, $F \in (\tilde{F}^{ur}, F^{ur}]$, the positive effect on social welfare due to more competition is not strong enough to compensate the negative effect accruing both from the cost of entry and from lower investments. Facilities based competition may be socially unattractive, although E's private benefit of entry may still be positive.

The figure visually shows that the inefficiency tends to disappear as β approaches to 1; this is due to the fact that the social benefit associated with the larger amount of investments

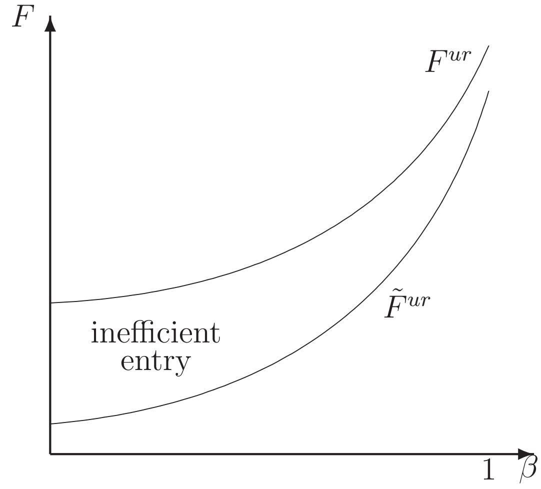

Figure 2: inefficient entry

in enhanced services due to E's entry increases with β at a higher rate then the increase in E's private benefit.

It is interesting to note that this result drives our paper in a direction that is the opposite to the one indicated by Bourreau and Dogan (2006). These authors use an inter-temporal framework to represent the entrant's choice between building an alternative network or buying access to the incumbent's infrastructure; in their framework in which investments in enhanced services are not considered, they find that, from a social perspective, the incumbent tends to charge a too low access price hence discouraging the entrant from rolling out its alternative infrastructure. On the contrary, in our paper the incumbent, by charging a too high access price, encourages E's facilities based entry and this turns out to generate a socially inefficient over-investment in enhanced services.

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.

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 (10). 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 (12); substituting the output levels (10) and rearranging, 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.[11]

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, solving the maximisation of (3) with respect to x_I yields the following level of investment:[12]

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

[11]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.

[12]The second order condition is satisfied.

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

$$\Pi_I^{*rnc}|_{b=0} = \frac{A^2}{9-2\beta^2}, \tag{15}$$

$$\Pi_E^{*rnc}|_{b=0} = \frac{9A^2}{(9-2\beta^2)^2}, \tag{16}$$

and

$$W^{*rnc}|_{b=0} = \frac{2A^2(18-\beta^2)}{(9-2\beta^2)^2}. \tag{17}$$

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 investing in its infrastructures, $\Pi_E^*|_{b=1}$ 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. 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. As F^{ur}, also F^{rnc} increases with β.

Basic algebra is enough to show that $F^{rnc} < F^{ur}$; 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.

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 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 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.[13] 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 networked entry, $W^{*}|_{b=1}$:

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

Proposition 3. *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. □

[13] 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.

As suggested by Proposition 3, the magnitude of the failures strictly depends on customers' evaluation for enhanced services; 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 $\beta \geq \sqrt{23 - \sqrt{241}}/4$, 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 given in expressions (10). 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 competitive, hence allowing the incumbent to increase its investments. Using $x_I^{rc}|_{b=0}$, the output produced by the entrant given in (10) becomes:

$$3\frac{A - a(2 - \beta^2)}{9 - 2\beta^2},$$

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

By substituting $q^*_I|_{b=0}$, $q^*_E|_{b=0}$ and $x^{rc}_I|_{b=0}$ obtained in this case, back into the social welfare function, it is possible to derive the level of welfare as a function of a:

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

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

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

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^{rc}_{forec}, 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, 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

[14]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 $a^{rc} = 0$. When $\beta \geq \sqrt{3}/2$, $\hat{a} \geq a^{rc}_{forec}$ and $a^{*rc} = A/(2-\beta^2)$. The second order condition for welfare maximization is satisfied.

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 an 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 can use a as an instrument to stimulate the deployment of new infrastructures, a result which is broadly consistent with the ladder of investment theory.[15]

We are finally ready 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:

$$\Pi_I^{*rc}|_{b=0} = \begin{cases} \frac{A^2}{9-2\beta^2} & \text{if } \beta < \frac{3}{8}\sqrt{2} \\ \frac{A^2(783\beta^2+176\beta^4-576\beta^6-162)^2}{2(31\beta^2-24\beta^4+9)^2} & \text{if } \frac{3}{8}\sqrt{2} \leq \beta < \frac{\sqrt{3}}{2} \\ \frac{(18-9\beta^2)A^2}{2(6-3\beta^2)^2} & \text{otherwise,} \end{cases} \tag{19}$$

$$\Pi_E^{*rc}|_{b=0} = \begin{cases} \frac{9A^2}{(9-2\beta^2)^2} & \text{if } \beta < \frac{3}{8}\sqrt{2} \\ \frac{(9-12\beta^2)^2A^2}{(31\beta^2-24\beta^4+9)^2} & \text{if } \frac{3}{8}\sqrt{2} \leq \beta < \frac{\sqrt{3}}{2} \\ 0 & \text{otherwise,} \end{cases} \tag{20}$$

$$W^{*rc}|_{b=0} = \begin{cases} \frac{2A^2(18-\beta^2)}{(9-2\beta^2)^2} & \text{if } \beta < \frac{3}{8}\sqrt{2} \\ \frac{3A^2(3+8\beta^2)}{2(9+31\beta^2-24\beta^4)} & \text{if } \frac{3}{8}\sqrt{2} \leq \beta < \frac{\sqrt{3}}{2} \\ \frac{A^2(3-\beta^2)}{2(2-\beta^2)^2} & \text{otherwise.} \end{cases} \tag{21}$$

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. *When the regulator is credibly committed to regulate the access charge at* a^{*rc}*: if* $\beta \geq \sqrt{3}/2$ *only facilities based entry occurs, provided that* $F \leq F^{ur}$*; when* $\beta < \sqrt{3}/2$

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

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:

$$F^{rc} = \begin{cases} F^{rnc} & if \quad \beta \leq \frac{3}{8}\sqrt{2} \\ \frac{2A^2(11663\beta^2 - 3276 - 1152\beta^8 + 6912\beta^6 - 14256\beta^4)}{(2\beta-3)^2(2\beta+3)^2} & otherwise \end{cases} \tag{22}$$

Proof. From a comparison between the level of profit that E gets by deploying its infrastructure, $\Pi^*_E|_{b=1}$ given in (9), and the amount it gets by seeking access to the incumbent's network, $\Pi^{*rc}_E|_{b=0}$ given in (20), the proposition follows immediately. □

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 the entry choice at the equilibrium. The same diagram is useful to represent the social efficiency of this form of regulation compared with the case without commitment; for this reason, we have drawn also the other relevant threshold levels of the fixed cost of networked entry, F^{rnc}, F^{un}, $\tilde{F}^{un}$ and $\tilde{F}^{rnc}$. In the diagram we have plotted the various thresholds with respect to β.[16]

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). 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

[16]Nota that the A is simply a scale parameter and it does not affect the shape of the functions.

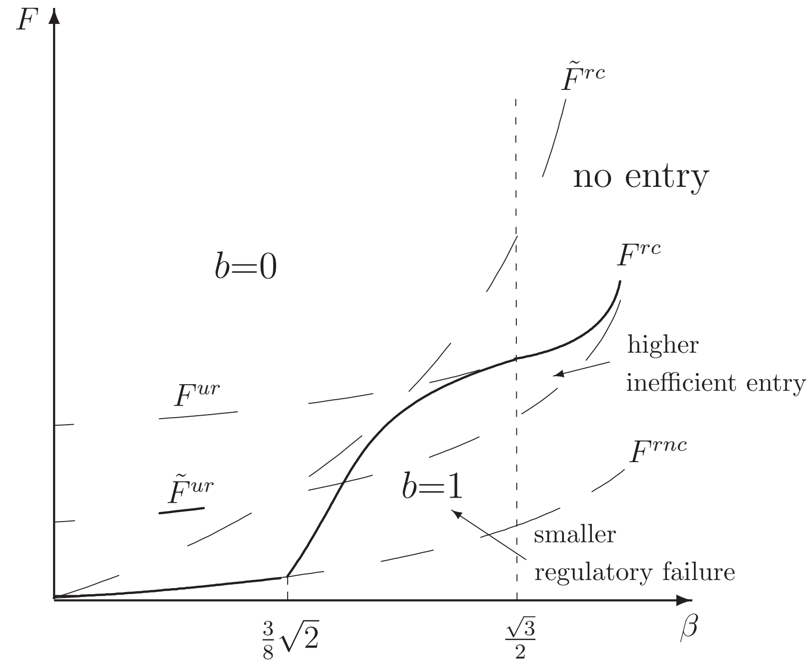

Figure 3: entry choices with access regulation and commitment

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}: this implies that we may still have a regulatory failure of type 1, but it tends to occur for 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 $\beta \in (3\sqrt{2}/8, \sqrt{3}/2)$.

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. *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, we can interpret this as a case in which the interconnection charge is regulated at a zero net payment.

B&K 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 to B&K 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.[17]

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

$$\Pi_{I,int}|_{b=1} = (A + \beta(x_I + x_E) - q_I - q_E)q_I - tq_I + tq_E - C(x_I), \tag{23}$$

and

$$\Pi_{E,int}|_{b=1} = (A + \beta(x_E + x_I) - q_I - q_E)q_E - tq_E + tq_I - C(x_E) - F, \tag{24}$$

where the subscript ^{int} reminds us that we are currently analyzing the model with bilateral

[17]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.

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:

$$t = argmax\Big[\Pi^{1/2}_{I,int}|_{b=1}\Pi^{1/2}_{E,int}|_{b=1}\Big]. \tag{25}$$

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.[18]

Solving expression (25), the negotiated interconnection charge given the amount of investments, is:

$$t^* = \frac{A+\beta(x_I+x_E)}{4}. \tag{26}$$

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. Replacing t^* into $\Pi_{i,int}(t)|_{b=1}$, $i = I, E$, 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 $x^*_{I,int} = x^*_{E,int} = A\beta/(2(2-\beta^2))$.[19] Interestingly, looking at these expressions, it emerges that when firms interconnect negotiating

[18] 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.

[19] Second order conditions are satisfied.

the terms of the reciprocal access, *i*) they are induced to invest more in enhanced services than with B&K interconnection and *ii*) economy-wide investments are identical to those that would be incurred by an unregulated monopolist, $x^*_{I,int} + x^*_{E,int} = x^{*ur}_I|_{b=0}$. 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 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:

$$\Pi^*_{I,int}|_{b=1} = \frac{A^2\left(4-\beta^2\right)}{8\left(2-\beta^2\right)^2}, \quad \text{and} \quad \Pi^*_{E,int}|_{b=1} = \Pi^*_{I,int}|_{b=1} - F, \tag{27}$$

and

$$W^*_{int}|_{b=1} = \frac{A^2\left(6-\beta^2\right)}{4\left(2-\beta^2\right)^2} - F. \tag{28}$$

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 $\Pi^*_{E,int}|_{b=1} \geq 0$, that is when $F \leq F^{ur}_{int}$, where $F^{ur}_{int} = A^2\left(4-\beta^2\right)/\left(8\left(2-\beta^2\right)^2\right)$. 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 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. In other words, bilateral access stimulates infrastructure competition.

This result raises a further interesting issue to investigate: in Proposition 1 we have discussed the conditions according to which without regulation and with B&K interconnection, inefficient entry occurs; it is natural to extend the analysis to the case with bilateral access.

Proposition 5. *Consider the unregulated scenario; when networked operators negotiate a* *common interconnection charge, more inefficient entry occurs then with B&K interconnection.*

Proof. The Proof is straightforward. Using the welfare expressions (28) and (13), it is possible to derive the threshold level for the entrant's fixed cost such that $W^{*ur}|_{b=0}=W^{*}_{int}|_{b=1}$: $\tilde{F}^{ur}_{int} = \beta^2 A^2/(4(2-\beta^2)^2)$. This level represents the counterpart of (14) with negotiated access; simple algebra reveals that $\tilde{F}^{ur}_{int} < \tilde{F}^{ur}$. This fact combined with $F^{ur}_{int} > F^{ur}$ is enough to prove the Proposition. □

More inefficient entry translates 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 (27)-(9) and (28)-(11) 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. Nonetheless, it is possible to show that for β assuming large values, the welfare loss of bilateral interconnection becomes smaller.

Finally, let us move on to the scenario with regulated access. For ease of exposition, we focus only to 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 emerge also when β is small (see Figure 4).

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 to not 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. While in the long run competition between alternative networks may emerge, in the short run only the incumbent controls an access network and this justifies the intervention of a social maximizing regulator aimed at determining the conditions to access to incumbent's infrastructure.

Consistently with existing economic literature, we find that when the access charge is not regulated, the incumbent forecloses the entrant by fixing a sufficiently high access price; however, in this case there is a possibly wide range of infrastructure investment cost within which infrastructured entry occurs even though it is not socially optimal.

When access charges are regulated ex-post (i.e. there is not regulatory commitment) regulatory failures may emerge, since service based entry occurs even when infrastructured entry would be optimal (and it would emerge without regulation). When access charge is regulated ex-ante we show that regulatory failures can be reduced.

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 and Keep interconnection regime.

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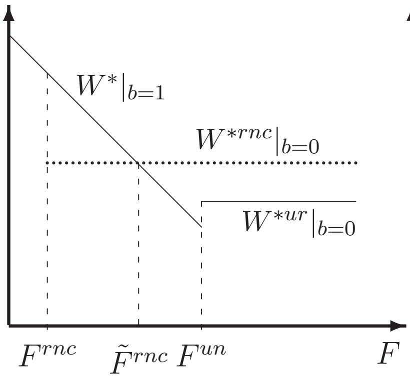

Figure 4: $\beta < \underline{\beta}$

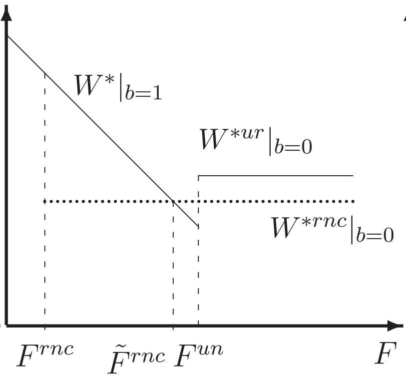

Figure 5: $\underline{\beta} < \beta < \overline{\beta}$

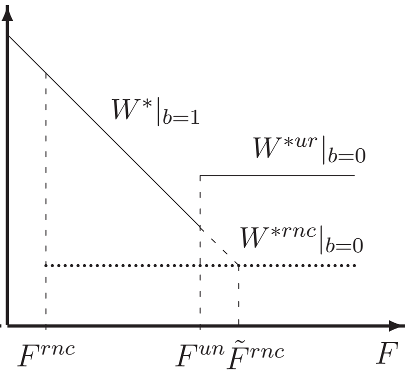

Figure 6: $\beta > \overline{\beta}$

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, while with access regulation the social welfare is $W^*|_{b=1}$ for $F \leq F^{rnc}$ and $W^{*rnc}|_{b=0}$ 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:[20]

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. □

[20]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 (28), for $F \leq F^{ur}_{int}$ and $W^{*ur}_{int}|_{b=0}$, defined in expression (13), 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 expression (17), 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:

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

while the amount of welfare without regulation is given by:

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

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 prove 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: The model with partial spillover.

In the paper we have analyzed the model with complete spillover; one may wonder wether our results still hold when, as it is more generally the case, the spillover effect is not complete, formally when $\mu < \beta$. As it will become clear below, the equilibrium of the entry 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 unregulated case; absent access regulation, market equilibrium may still be inefficient from the social perspective. To understand this, let we define as $i)$ F_{ps}^{ur} the entrant's threshold level of the fixed cost of rolling out the network such that for $F \leq F_{ps}^{ur}$ entry occurs and, $ii)$ $\tilde{F}_{ps}^{ur}$ the threshold level such that $W_{ps}^{*ur}|_{b=0}=W_{ps}^{*}|_{b=1}$.[21] The main difference between complete and partial spillover is that a different form of inefficiency may emerge for some parameters' values; in particular, it is possible to prove the following result:[22]

Proposition A1. *If access charge is not regulated, there exist a subset M of pairs (μ, β) such that if $(\mu, \beta) \in M$, and $F \in (F_{ps}^{ur}, \tilde{F}_{ps}^{ur})$ entry does not occur but the social welfare would be higher with entry (lack of entry).*

We have drawn Figure 7 in order to provide a better understanding of this proposition. In a $(\mu X \beta)$ space, we have plotted the set of pairs (μ, β) that solve the equation $F_{ps}^{ur} = \tilde{F}_{ps}^{ur}$. The parabola drawn in Figure 7 is the set of pairs that solve this equation; therefore for all the points lying below the parabola, $F_{ps}^{ur} > \tilde{F}_{ps}^{ur}$ (i.e. excess of entry) while for those above it $F_{ps}^{ur} < \tilde{F}_{ps}^{ur}$ (i.e. lack of entry). The subset M is visually represented by all the points where lack of entry occurs at the unregulated equilibrium.

From the figure, it emerges that for β not too large, Proposition 1 (excess of entry) is still valid also in this partial spillover environment; independently of the degree of the spillover, for β approximately lower that 0.74, inefficient entry is the unique outcome. This is not surprising: when β is not too large, and consequently μ is not too large as well, the social value generated by the investments is lower than the private benefit enjoyed by the firms. This is true for both firms, but for E in particular: if F is not too large, E enters despite its choice is not socially desirable.

Things may change when the own demand effect is large; in this case, if the spillover is also sufficiently large, but not too much, the equilibrium may show lack of entry. More precisely, let

[21] The subscript ^{ps} indicates that we are in the partial spillover case.

[22] The Proof of the results presented in this Appendix are available at the URL `www.decon.unipd.it/personale/curri/manenti/academic/papers/LOI_appendix2.pdf`.

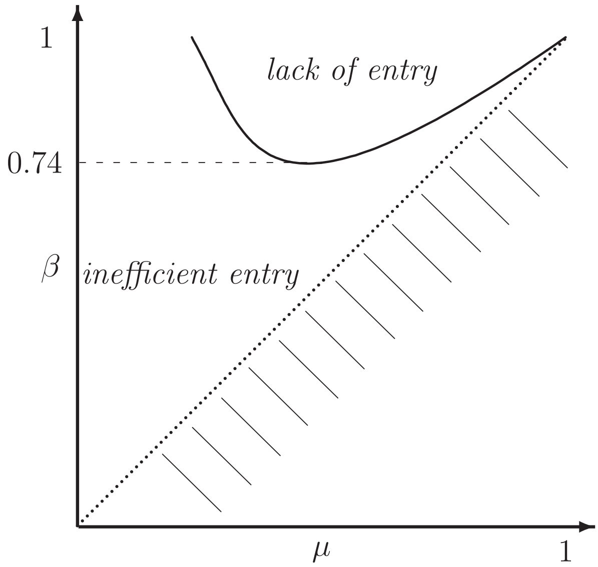

Figure 7: Inefficient entry with partial spillover

us assume that $\beta > 0.74$; three situations may appear: *i*) μ is small and the equilibrium shows inefficient entry, *ii*) μ takes larger values and the equilibrium generates lack of entry and *iii*) μ close to β with the model back again to inefficient entry.

All these cases, are characterized by β large, i.e. firms investments in enhanced services are highly valuable to firms' customers. Consider *i*); when the spillover is low, eventually $\mu = 0$, each firm is able to enjoy full benefit of its efforts; this overstimulates firms' investments. In particular, E's incentive to enter and to invest in enhanced services is stronger than the social benefit, which is smaller due to the low level of the spillover, and this explains the inefficiency. Case *ii*) is characterized by a larger spillover; firms investments have less the nature of private goods and, due to the large μ, they are socially desirable; in this case, firm i's private benefit of its investment is lower compared to the social value it generates and this explains why in this case E may decide not to enter despite its entry would be socially desirable.

Finally, in case *iii*) the spillover becomes very strong; this case perfectly mimics the scenario analyzed in section 2.1. Firms' investments become a public good and, following standard arguments, underinvestment occurs at the equilibrium: as we have already discussed above, E's entry becomes undesirable simply because, due to the large spillover, economy-wide investments become lower than under monopoly.

Let us move on to study the model with access regulation. The main difference between the complete and the partial spillover case is that for extremely incomplete spillover, access regulation does not necessarily entice entry. More precisely, when the regulator does not commit to an access charge schedule before operators' investment decisions have been taken, it is possible to prove the following:

Proposition A2. *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* $F \leq F_{ps}^{*ur}$.

This Proposition shows that when the direct value generated by firms investments is sufficiently strong and the spillover is sufficiently low, the entrant may find it optimal not to enter the market at all. In particular, for strongly asymmetric spillover ($\beta > \sqrt{3}/2$ 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[23] 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.

We are left with the case of committed regulation. Again, the equilibrium of the game is qualitatively identical to the case with complete spillover. Obviously, the optimal access charge and the decision to enter are quantitatively different since they also depend on μ.[24]

[23]This result is reminiscent of similar arguments obtained in Foros (2004) in a framework without facilities based entry.

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